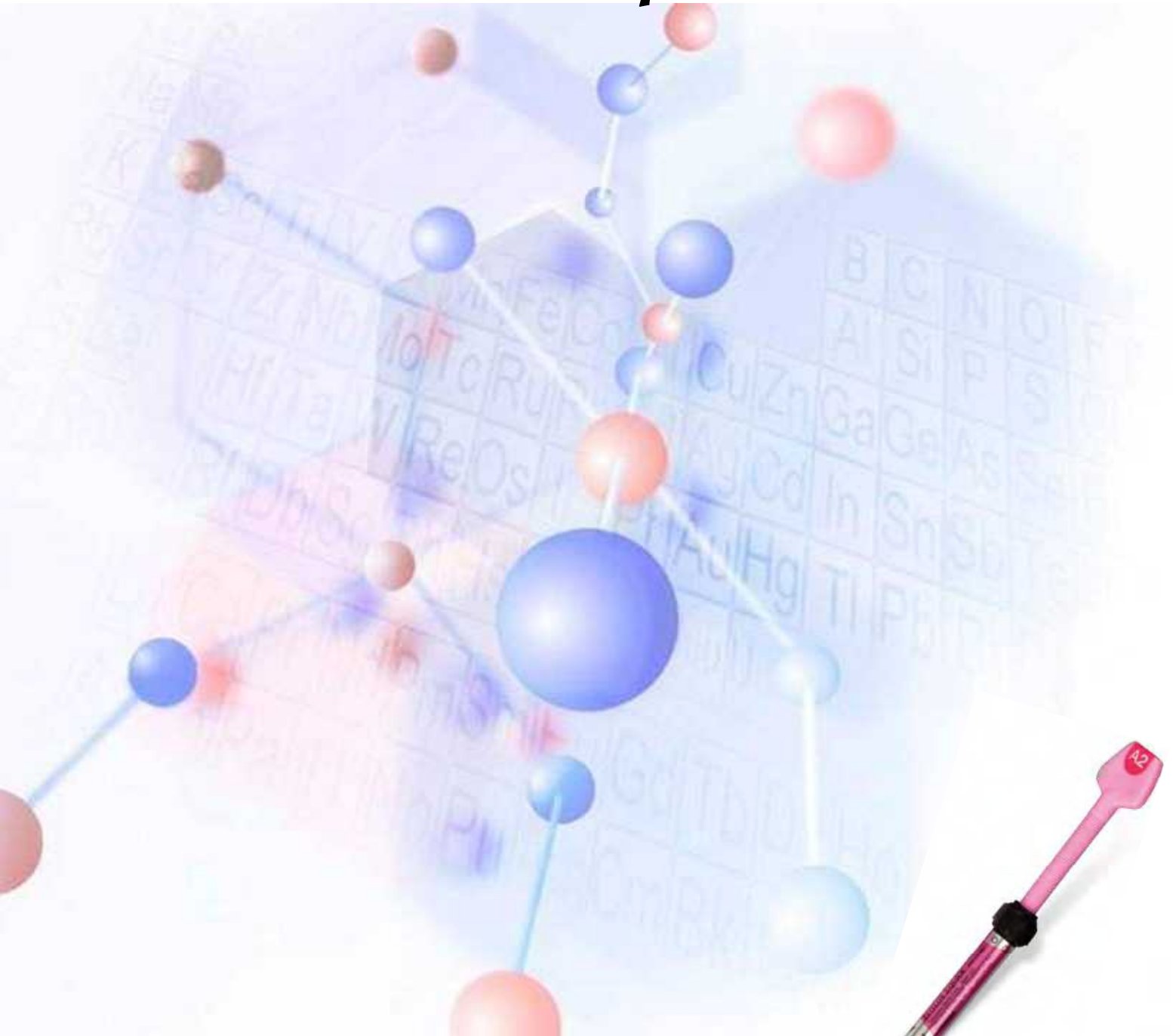


# *Technical Report*



Supra-nano-fill Dental Restorative Material

Sigma  
**ESTELITE  $\Sigma$  QUICK** 

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## 1. Introduction

Tokuyama Dental has developed various light-curing dental restorative composite resins that take advantage of its proprietary supra-nano spherical filler technology. Represented by Palfique Estelite® Paste, Estelite® Σ, and Palfique Estelite® LV, these products have acquired a reputation for outstanding aesthetics and gloss.

In 2005, Tokuyama Dental launched Estelite® Flow Quick, a new flowable composite resin, based on a new catalyst technology (RAP technology™) and a proprietary filler technology. This approach results in remarkably fast curing compared to conventional flowable resins (requiring approximately 1/3 the time). Due to RAP technology™, Estelite® Flow Quick features high conversion and leading levels of filler content (71 wt%) among flowable composite resins. It offers outstanding scientific and engineering properties not found with conventional flowable composite resins.

The RAP technology™ used in Estelite® Flow Quick was applied to universal composite resins and new composite resins, resulting in Estelite® Σ Quick, released in November 2007.

Estelite® Σ Quick provides outstanding esthetics and high polymerization activity based on (1) improvements in matrix conversion and stability in ambient light provided by RAP technology™ and (2) outstanding esthetic aspects provided by its supra-nano monodispersing spherical filler.

The subsequent sections describe the technical background, features, and properties of Estelite® Σ Quick.

## 2. Background technology

Estelite®  $\Sigma$  Quick offers the following two technical features:

- (1) Adoption of a Radical Amplified Photopolymerization initiator (RAP technology™)
- (2) Using supra-nano monodispersing spherical filler

The following subsections describe these features and the benefits they confer.

### 2.1. Radical Amplified Photopolymerization initiator (RAP technology™)

The catalyst technology adopted for Estelite®  $\Sigma$  Quick is the Radical Amplified Photo-polymerization initiator (RAP technology™) used in Estelite® Flow Quick. As a major feature, the initiator balances the high polymerization activity needed to cure the resin with short exposure times (1/3 of that required by conventional products) and stability in ambient lighting. These two traits are often regarded as mutually conflicting, since shorter curing times tend to reduce stability. However, this unique catalyst technology achieves a balance of these two factors. Figure 1 is a schematic diagram of RAP technology™.

Conventional photo-polymerization initiators consist of camphorquinone (hereafter abbreviated CQ) and amines. The mechanism of action involves the excitation of CQ by irradiation, followed by the abstraction of hydrogen in the alpha-position by the excited CQ, producing amine-derived radicals. The amine-derived radicals function as the polymerization initiator and react with monomers to generate polymers, ultimately producing the curing effect. In this catalyst system, CQ is consumed as it changes to CQ-H in polymerization initiator generation. Unlike CQ, CQ-H is not excited by light. This means a single molecule of CQ can only produce a single polymerization initiator molecule.

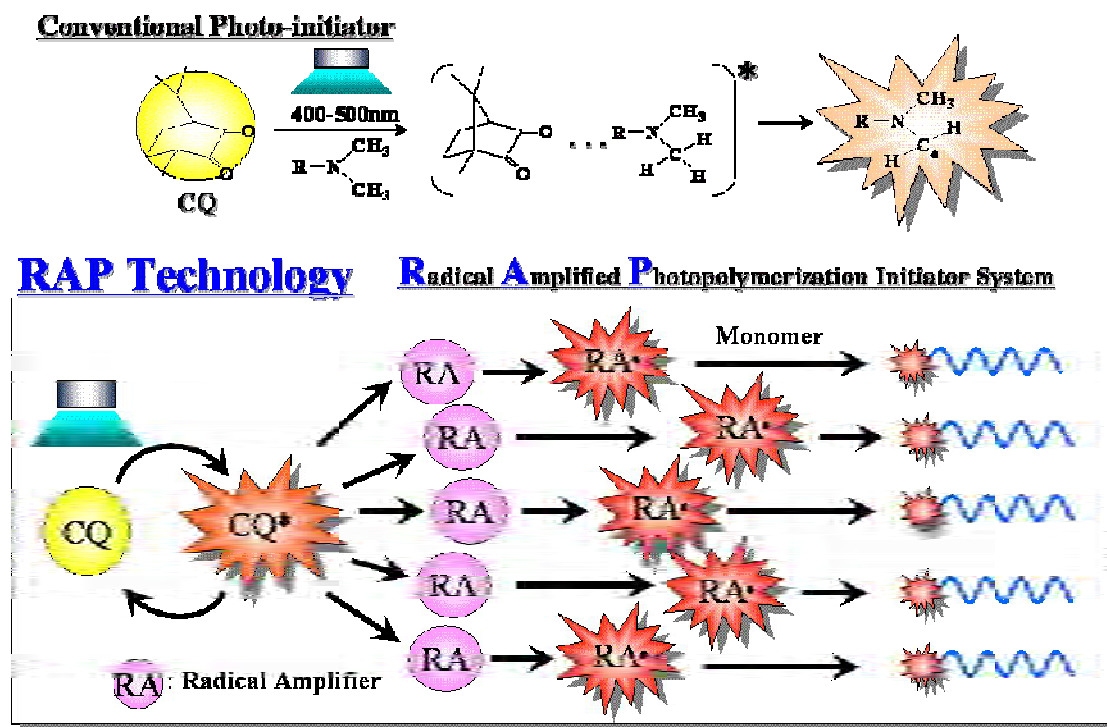


Fig.1 Radical Amplified Polymerization initiator system (RAP technology™)

With the radical amplified photo-polymerization initiator, the initial stage of CQ excitation by light is the same as in conventional systems. However, energy is transferred to the radical amplifier (hereafter abbreviated RA); the RA is subsequently excited, then allowed to decompose to produce RA-derived radicals. These radicals act as the polymerization initiator and react with monomers to generate polymers, producing the curing effect. After transferring energy to RA, the excited CQ returns to the ground state and is once again excited by irradiation and contributes to the reaction for polymerization initiator species generation. In other words, with RAP technology™, CQ is recycled within the polymerization initiator generation reaction, and a single CQ molecule can produce multiple initiator radicals. Thus, in addition to being highly active, RAP initiators can be used with smaller CQ volumes than conventional catalysts and improve stability in ambient lighting, including dental and fluorescent lights. The present initiator system is also free of chemical reactions between two molecule species, such as hydrogen abstraction in conventional systems, allowing shorter times from the photo-excitation of CQ to initiator radical generation.

To confirm that RAP technology™ increases polymerization rates, we compared the amount of residual monomers after a light cure for two different composite resins: Estelite® Σ Quick, which contains a radical amplified photopolymerization initiator, and Estelite® Σ, which contains a conventional photopolymerization initiator composed of CQ and amines. Figure 2 shows the results.

Fig. 2 indicates that the radical amplified photopolymerization initiator significantly reduces residual monomers compared to the conventional CQ-amine photopolymerization initiator for both 10-second and 30-second exposures. This holds true even when comparing Estelite® Σ Quick after 10-seconds of exposure to Estelite® Σ after 30-seconds of exposure. These results support the mechanism of action shown in Fig. 1.

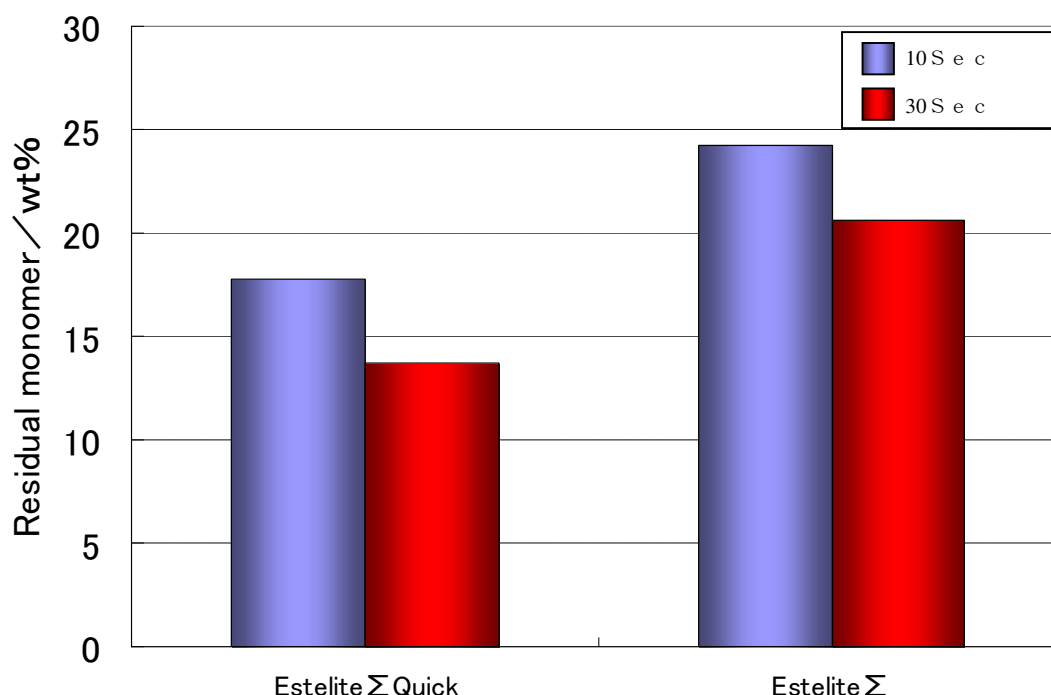


Fig.2 Residual monomer

## 2.2. Supra-nano monodispersing spherical filler

The world-class technologies embodied in the supra-nano monodispersing spherical filler are a signal feature of Tokuyama Dental's composite resins. This filler easily produces extremely high surface gloss. A brief summary of its features is given below.

- (1) Filler particle diameters are relatively uniform, and the particle size can be controlled by filler synthesis reaction times.
- (2) The refractive index is easily adjusted by adjusting the material compounding ratio.

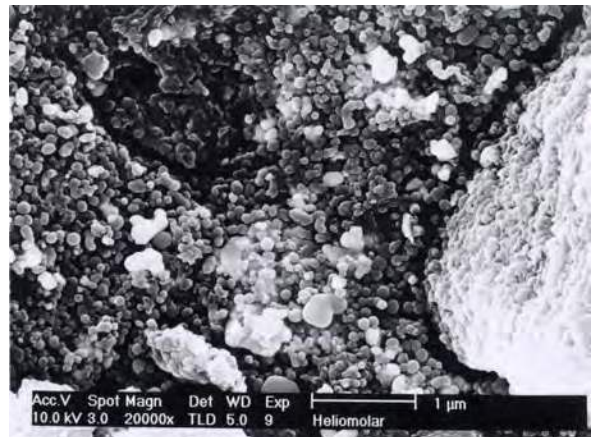
To achieve high esthetic qualities, Estelite®  $\Sigma$  Quick has the same filler composition as Estelite®  $\Sigma$ : a 0.2- $\mu\text{m}$  monodispersing spherical filler (Si-Zr). Particle diameters of 0.2  $\mu\text{m}$  are known to produce the best balance of material properties and esthetics.<sup>1)</sup> SEM images of the filler used in Estelite®  $\Sigma$  Quick and the fillers used in composite resins of other manufacturers are given below. Whereas the fillers used in the composite resins of other manufacturers consist of irregular fillers having different particle diameters (hybrid type), the filler used in Estelite®  $\Sigma$  Quick has a fine, uniform diameter.



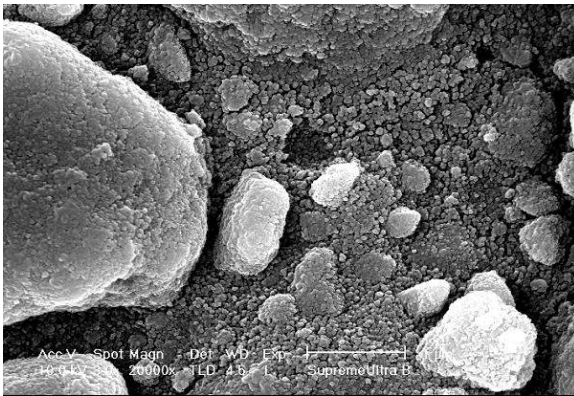
Estelite $\Sigma$  Quick ( $\times 20,000$ )



Tetric Evo Ceram



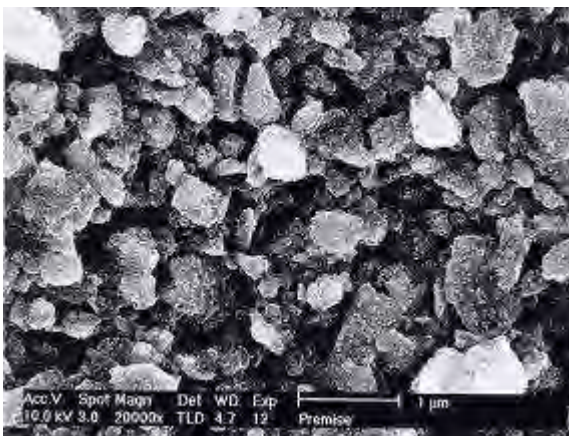
Heliomolar



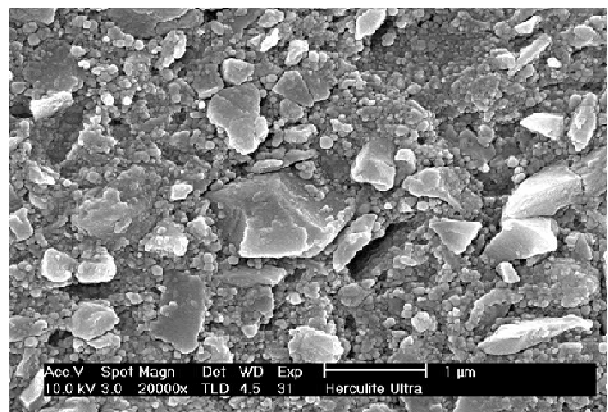
Filtek Supreme Ultra



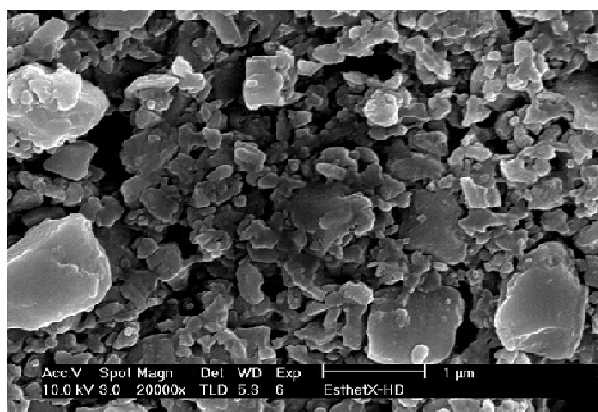
Filtek SupremeXT



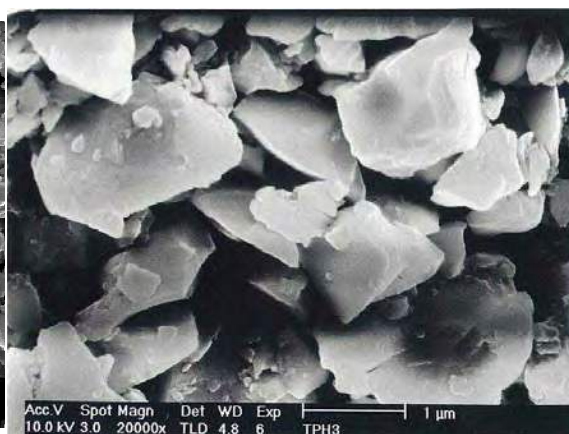
Premeise



Herculite Ultra



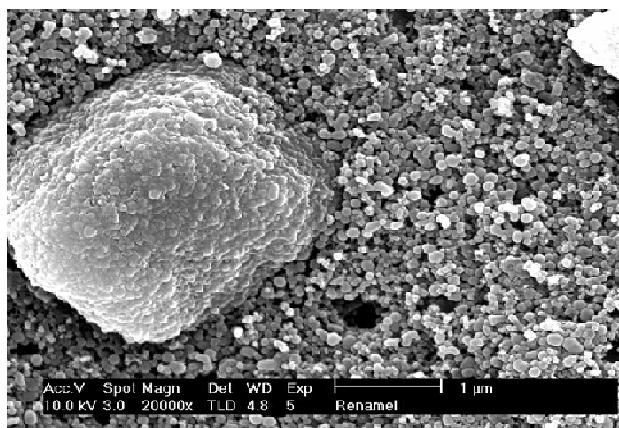
Esthet-X HD



TPH3



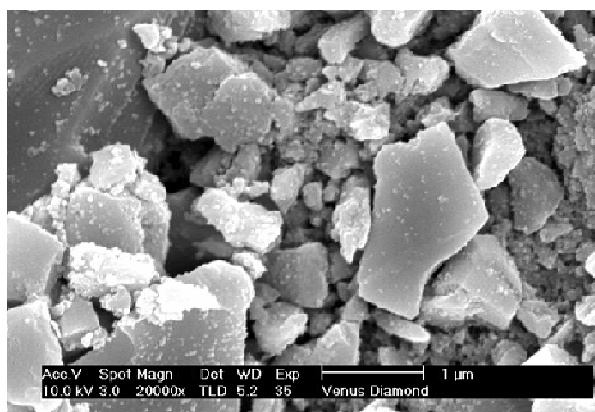
CeramX-mono



Renamel Microfill



Amaris



Venus Diamond



Gradia Direct



Clearfil Majesty

Supra-nano is the size which can be defined to be ranged smaller than micron and bigger than nanometer (between 100 nm and 1000nm). Mean filler size of Estelite® Σ Quick is 200 nm so we can call it supra-nano-fill composite.

Fig.3 Correlation between particle size, filler content and compressive strength

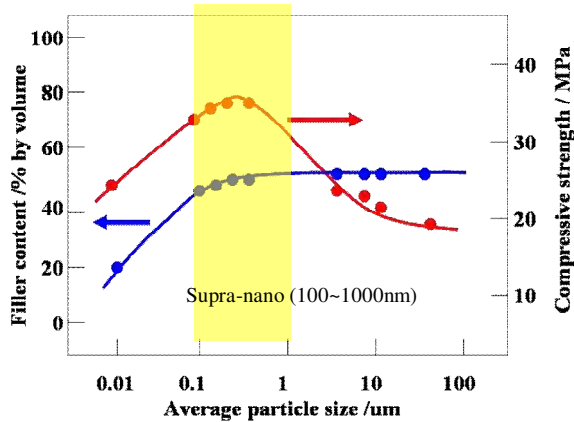


Fig.4 Correlation between particle size, surface roughness and surface hardness

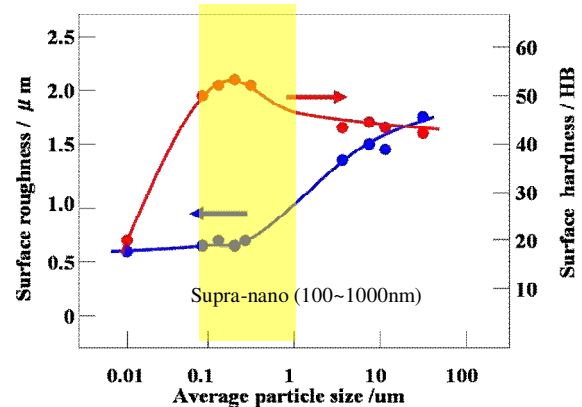


Fig. 3 gives the correlation between filler particle size and filler content and compressive strength. Fig. 4 gives the correlation between filler particle size and surface roughness and hardness. From Fig. 3, we see that filler content begins to fall significantly below 0.1 μm, but is nearly constant at sizes above that. In addition, we observe maximum compressive strength at particles size ranging from 0.1 to 0.5 μm. From Fig. 4, we see that surface roughness decreases with particle sizes down to approx. 0.5 μm but remains the same at the sizes below 0.5μm. Surface hardness attains the highest value at particle sizes ranging from 0.1 to 0.5 μm. Based on the above results, we conclude that the best balance between esthetics and physical characteristics can be achieved by using supra-nano (100~1000nm) sized particles.

### 3. Features of Estelite® $\Sigma$ Quick

Estelite®  $\Sigma$  Quick has the four following features:

- (1) Fast-curing
- (2) Outstanding scientific and engineering properties
- (3) Outstanding esthetics
- (4) Ease of use

The following subsections describe these features in detail.

#### 3.1. Effects of radical amplified photopolymerization initiator

##### 3.1.1. Cure rate

One trait of Estelite®  $\Sigma$  Quick is its cure rate. Conventional composite resins generally require approximately 20-30 seconds of exposure time, depending on the shade of the paste and intensity of the light-curing unit. In contrast, Estelite®  $\Sigma$  Quick requires exposures of 10 seconds or less. Such short exposure times are especially helpful for restoration work accompanied by incremental filling or when the patient is a small child or has heavy salivary flow.

Here we evaluate the cure rate of Estelite®  $\Sigma$  Quick in terms of hardness and depth of cure with various light-curing units. Table 1 lists the characteristics of the light-curing units used.

Figure 5 shows the correlation between exposure time and surface hardness (Vickers hardness) with various light-curing units. Figure 6 shows the correlation between exposure time and depth of cure.

Table 1: Performance and characteristics of light-curing units

|                   | Light source | Wavelength (nm) | Light intensity (mW/cm <sup>2</sup> ) | Characteristics                               |
|-------------------|--------------|-----------------|---------------------------------------|---|
| Optilux LCT       | Halogen lamp | 400–500         | 800                                   | Most general type as dental light-curing unit |
| Elipar Free Light | LED          | 440–495         | 260                                   | LED light-curing unit. Low light intensity.   |
| Apollo 95E        | Xenon lamp   | 430–500         | 950                                   | High light intensity                          |

As shown in Fig. 5, Estelite®  $\Sigma$  Quick is generally unaffected by the light source type, exhibiting the same surface hardness regardless of light-curing unit. In addition, surface hardness increases with shorter exposure times for Estelite®  $\Sigma$  Quick than for Estelite®  $\Sigma$ . The surface hardness of Estelite®  $\Sigma$  Quick achieved after 10 seconds of exposure exceeds that of Estelite®  $\Sigma$  obtained after 30 seconds of exposure.

In contrast to surface hardness, no meaningful difference was observed for depth of cure. The thickness of CR in a layer must be 2 mm or less when filling a cavity with Estelite®  $\Sigma$  Quick.

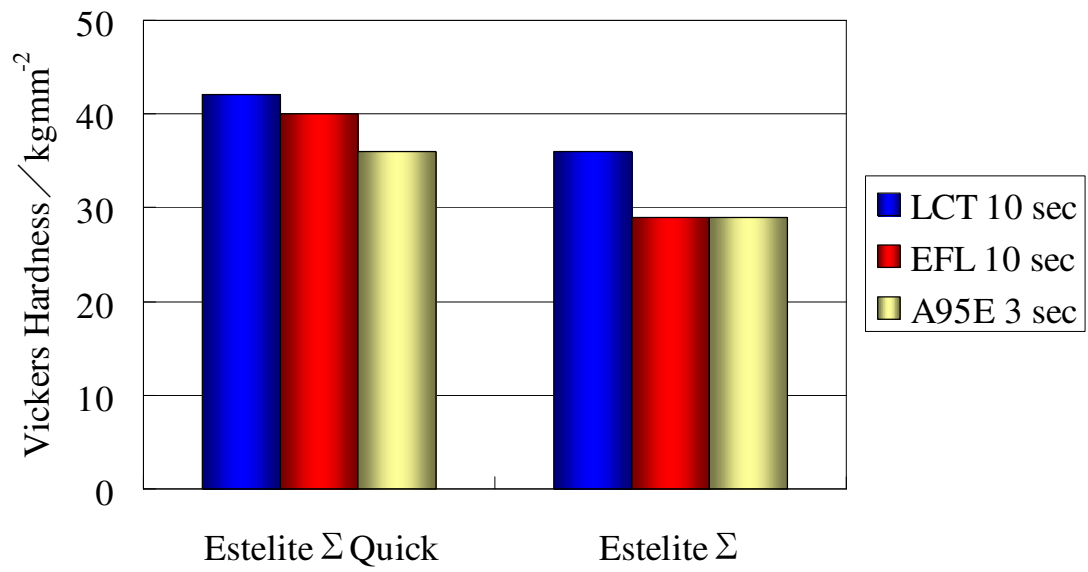


Fig.5 Vickers Hardness

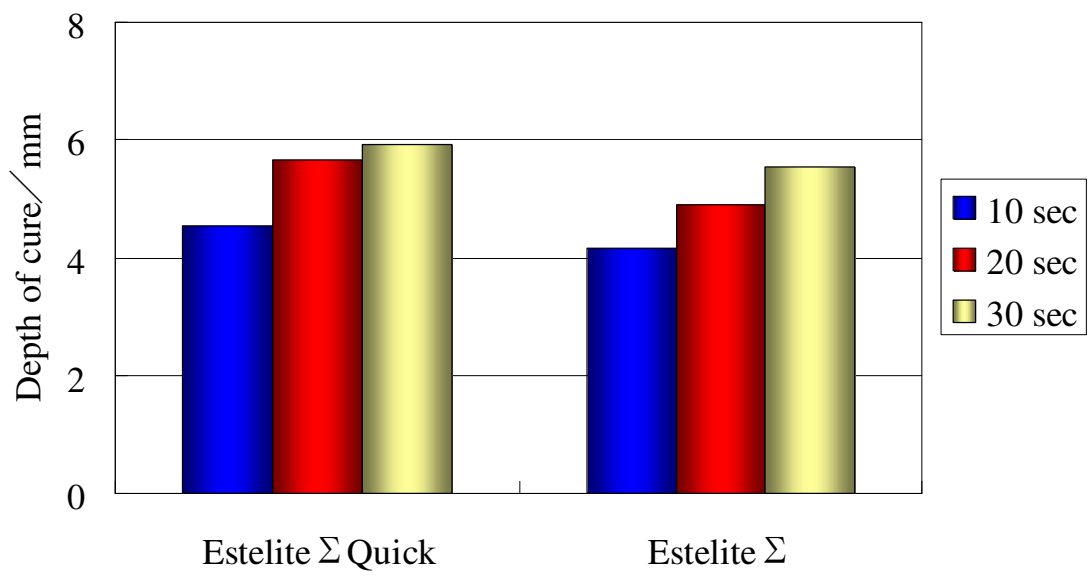


Fig.6 Depth of cure

### 3.1.2. Stability in ambient light

In the past, high polymerization activity with short exposures could only be achieved by increasing the amount of photopolymerization initiator used. However, increasing the amount of the catalyst decreases the stability of the resin in ambient light. Additionally, the viscosity of the paste may increase during the filling step in clinical services, making the resin impossible to sculpt and requiring a second filling attempt. In addition, increasing the amount of catalyst can also exacerbate changes in color before and after polymerization. While increasing the amount of photopolymerization initiator is believed to result in various undesirable effects, RAP technology™ can provide both polymerization activity and stability in ambient light, as described in detail in 2.1. Figure 7 compares stability under ambient light (10,000 lx of dental light) between Estelite® Σ Quick and other commercially available composite resins.

As shown in Fig. 7, Estelite® Σ Quick cures with short exposures and features approximately 1.6 times (90 seconds) higher stability in ambient light than Estelite® Σ. Estelite® Σ Quick offers stability in ambient light equivalent to products from other manufacturers, with working times slightly longer than average. This gives clinicians more time to perform filling and other steps.

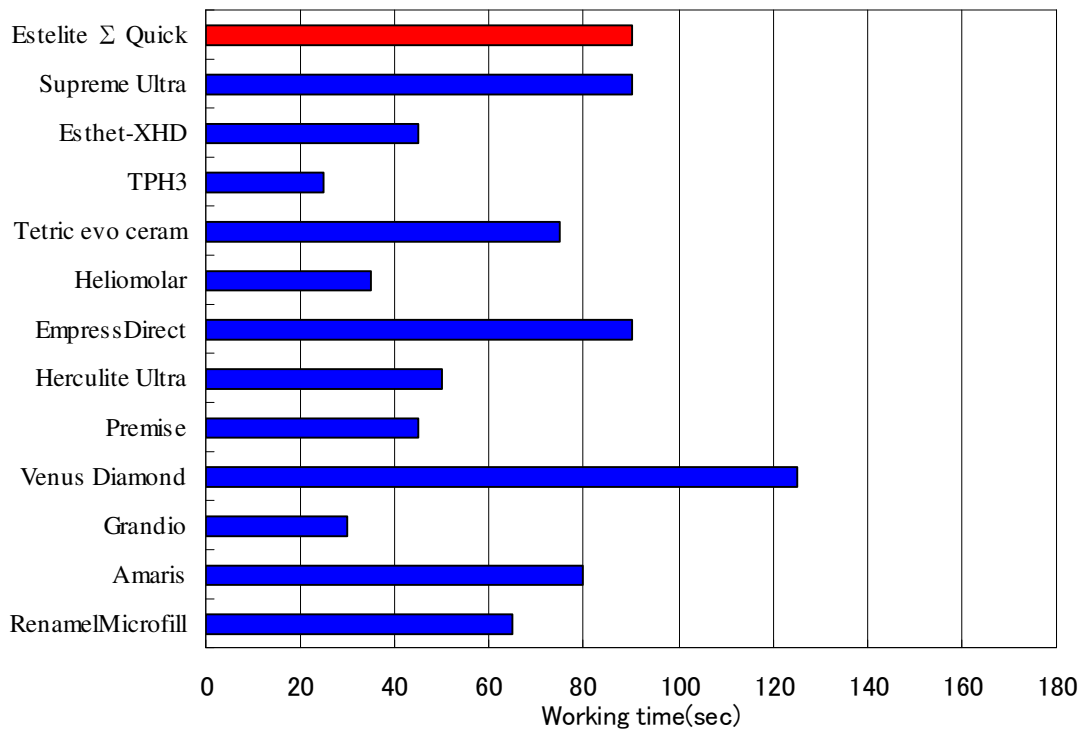


Fig.7 Working time (10,000lux/dental light)

### 3.2. Scientific and engineering properties

In addition to the superior polymerization characteristics provided by RAP technology™, Estelite®  $\Sigma$  Quick offers various outstanding properties as a dental restorative composite resin. When fabricating a sample with light exposure, we used the Optilux LC-T light-curing unit and exposed the sample for 10 seconds in the case of Estelite®  $\Sigma$  Quick and for the recommended exposure time in the case of other composite resins.

#### 3.2.1. Polymerization shrinkage

We measured polymerization shrinkage by our original method. Figure 8 is a schematic diagram of the measurement method. This method can measure shrinkage in the cavity floor (interface between the composite resin and plunger in Fig. 8) when the composite resin is placed into a cavity and exposed to light in a clinical procedure. This permits evaluation of shrinkage under conditions closer to those encountered in actual clinical settings.

Figure 9-1 shows the polymerization shrinkage of Estelite®  $\Sigma$  Quick and other commercially available composite resins. The graph indicates shrinkage 3 minutes after the start of light exposure.

The polymerization shrinkage of Estelite®  $\Sigma$  Quick is 1.3%, or the same as for Estelite®  $\Sigma$ . This is the minimum level among commercially-available composite resins. As with Estelite®  $\Sigma$ , this result is due to the high filler volume content made possible by the combination of supra-nano monodispersing spherical filler and organic composite filler.

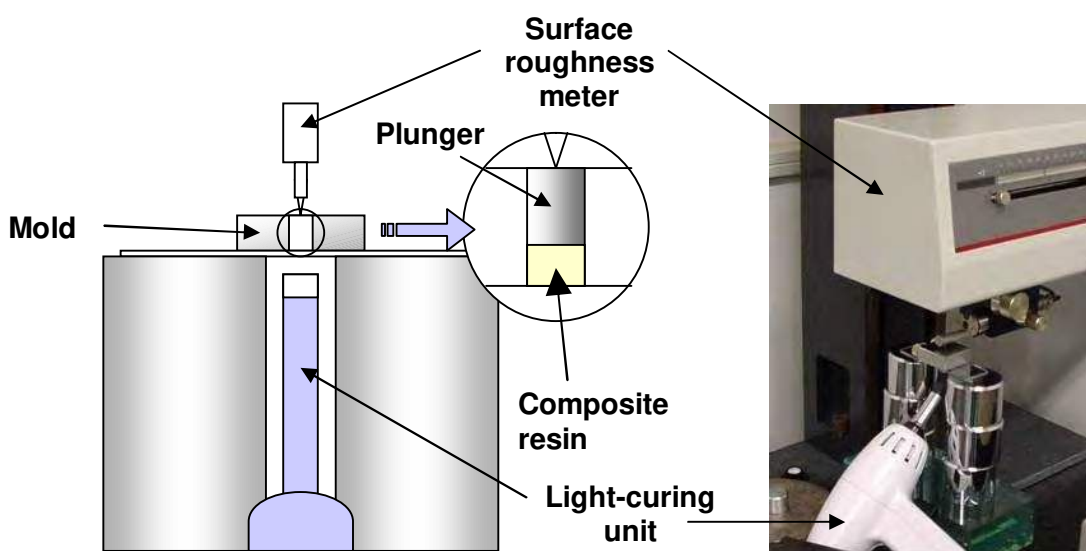


Fig.8 Method of polymerization shrinkage

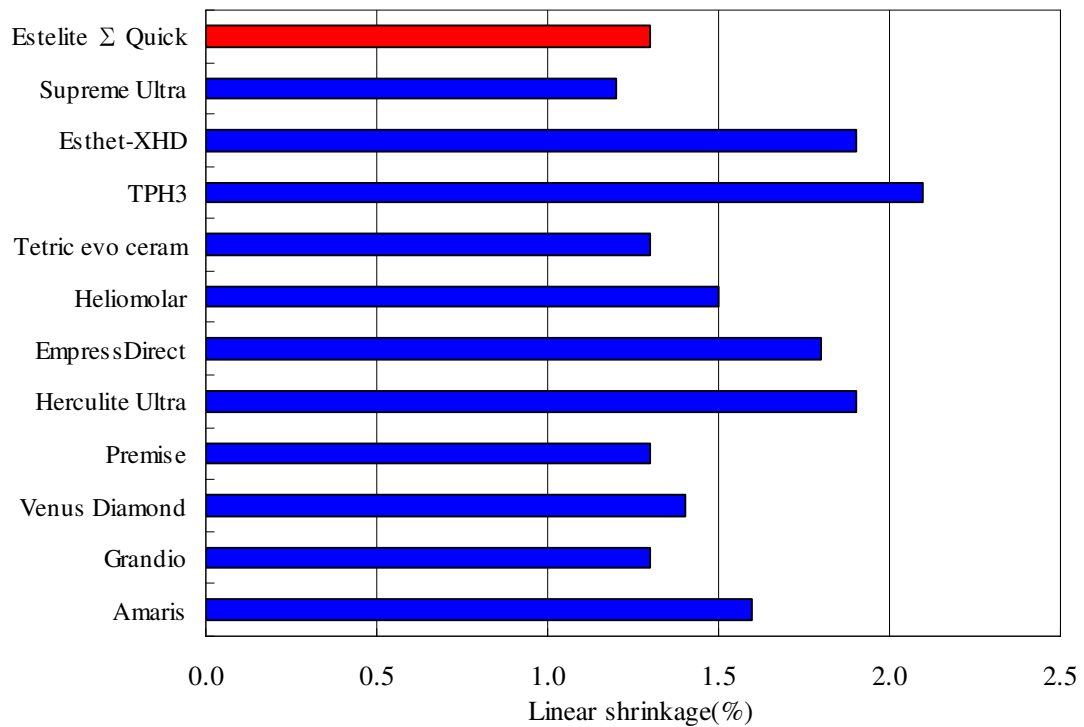


Fig.9-1 Polymerization shrinkage(linear%)

We asked the Department of Operative Dentistry, Nihon University School of Dentistry to evaluate polymerization shrinkage (Figure 9-2). <sup>2)</sup> As Fig. 9-2 shows, the university evaluation also points to the low polymerization shrinkage of Estelite® Σ Quick.

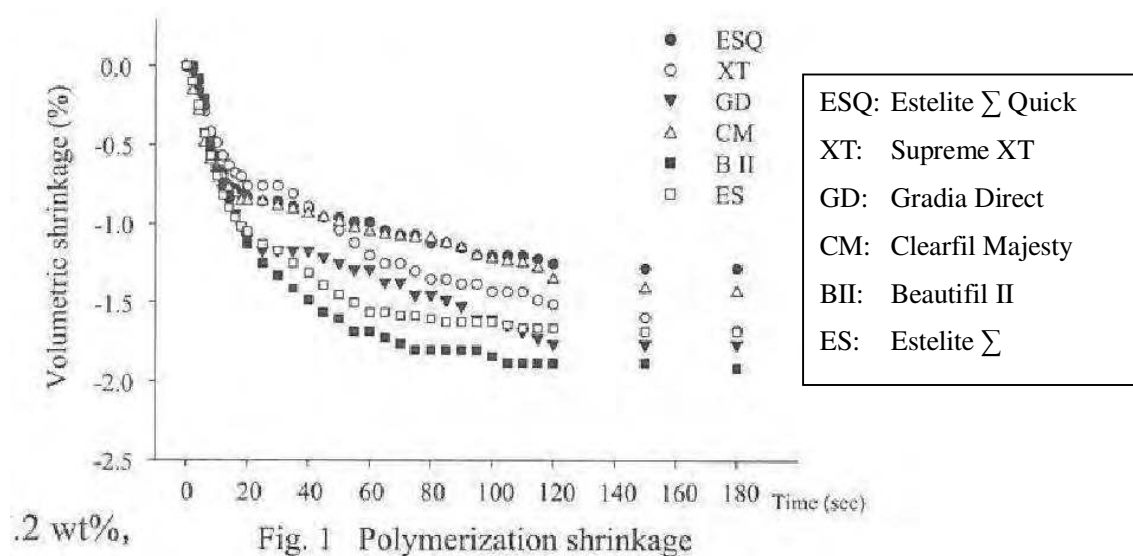


Fig.9-2 Polymerization shrinkage (vol%)

### 3.2.2. Polymerization shrinkage stress

We asked the Department of Operative Dentistry at the Nihon University School of Dentistry to evaluate the polymerization shrinkage stress of Estelite®  $\Sigma$  Quick.<sup>2)</sup> The evaluation was performed based on measurements performed with our own equipment (Figure 10). Figure 11 shows the results.

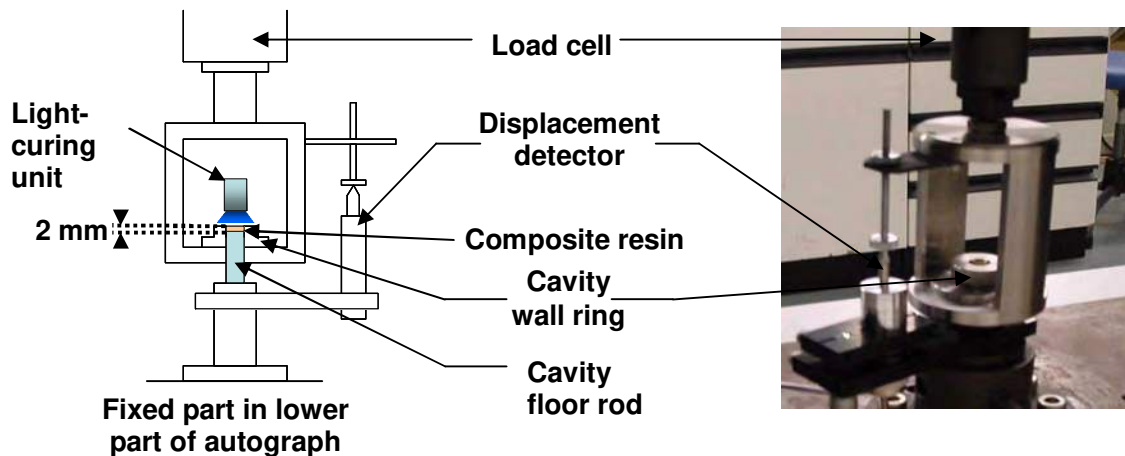


Fig.10 Method of shrinkage stress

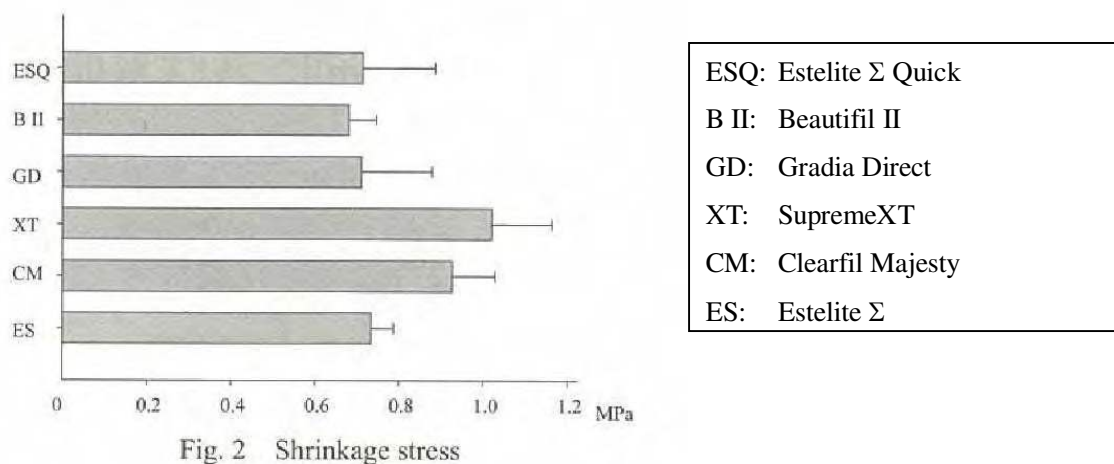


Fig.11 Shrinkage stress

In general, shrinkage increases with curing speed. The latest crop of light-curing units featuring strong light intensity provides two or more light exposure modes to reduce polymerization shrinkage stress. As indicated in Fig. 11, Estelite®  $\Sigma$  Quick features approximately the same polymerization shrinkage stress as Estelite®  $\Sigma$ , despite its fast-curing characteristics. It features average characteristics in this regard compared to products from other manufacturers.

### 3.2.3. Wear characteristics

We examined the wear characteristics of composite resins in terms of wear resistance of the resin and the human tooth by the method shown in Figure 12. Figure 13 gives the results. Estelite®  $\Sigma$  Quick demonstrated a good balance between volume loss of CR and wear on human teeth. As with Estelite®  $\Sigma$ , Estelite®  $\Sigma$  Quick itself resists wear without causing unusual wear in opposing teeth.

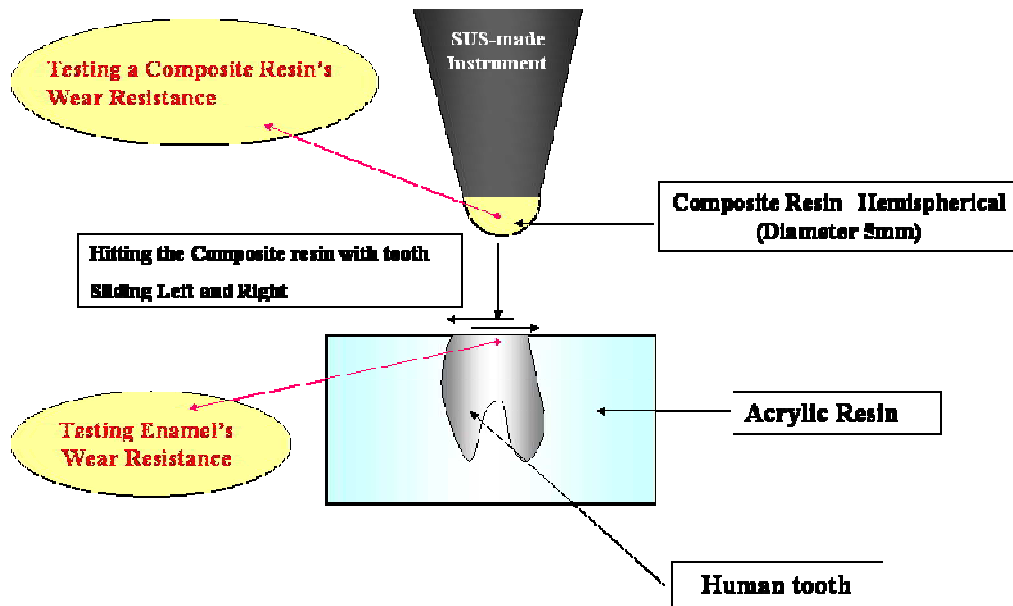


Fig.12 Method of wear resistance

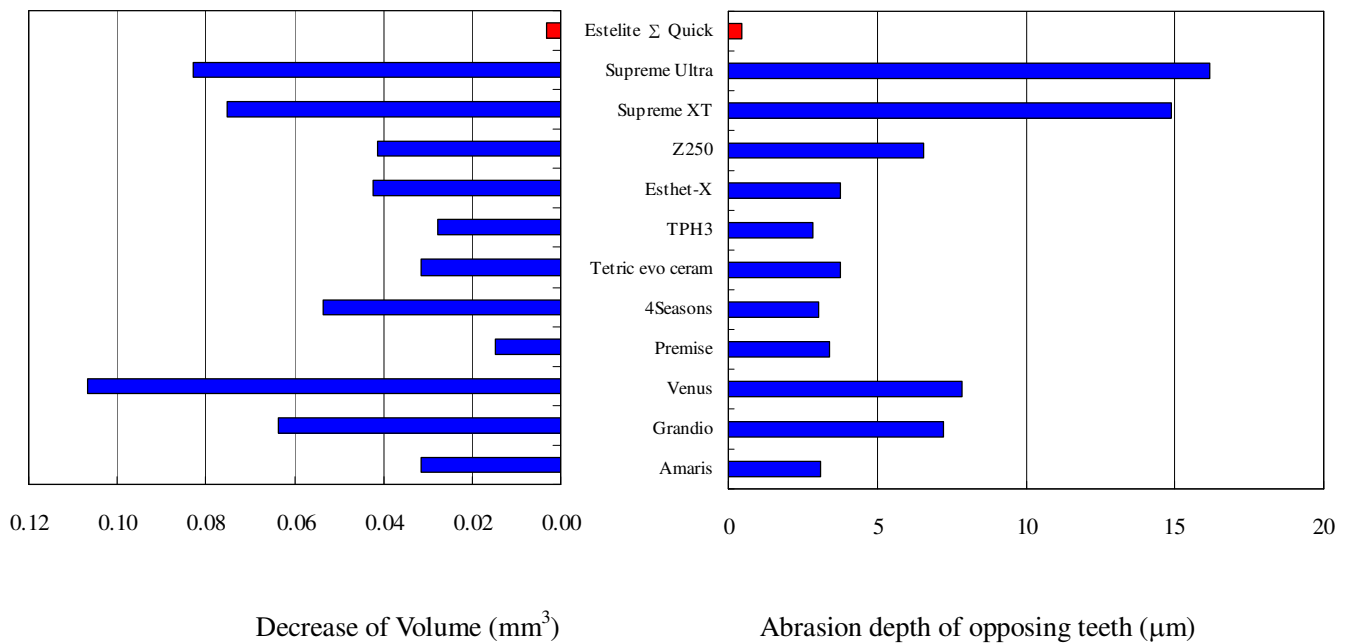
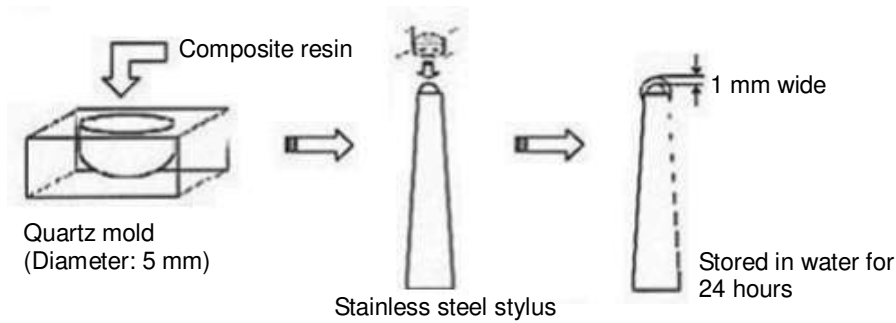


Fig.13 Wear properties

We also asked the Tokyo Medical and Dental University to evaluate the tendency of resin to wear down opposing teeth.<sup>3)</sup> Figure 14 illustrates the evaluation method. Figures 15 and 16 show the evaluation results. As Figures 15 and 16 show, the university evaluation demonstrates superior wear characteristics of Estelite®  $\Sigma$  Quick.



The bottom sample is prepared as follows: An extracted human premolar is embedded at the center of an acrylic tube with internal diameter of 22 mm with a fast-curing resin (Unifast II, GC), stored in water at temperatures of 37 degrees Celsius for 24 hours and polished with waterproof abrasive paper to 1200 grit to expose the flat surface of the enamel.



An impingement wear testing machine (K655-05, Tokyo Giken Inc.) was used for the test, which was performed in air for 50,000 cycles, each consisting of an impact and sliding motion at a load of 5.8 kgf and stroke width of 1 mm.

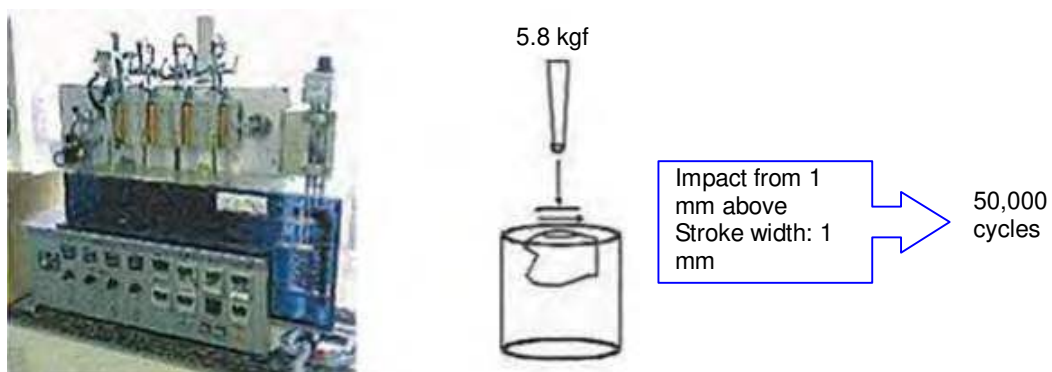


Fig.14 Method of wear resistance

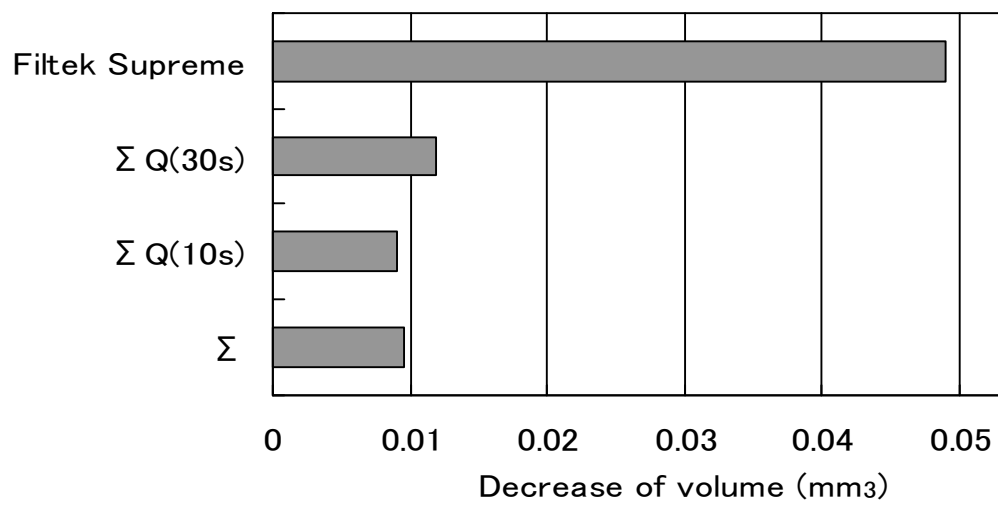


Fig. 15 Decrease of Volume (mm<sup>3</sup>)

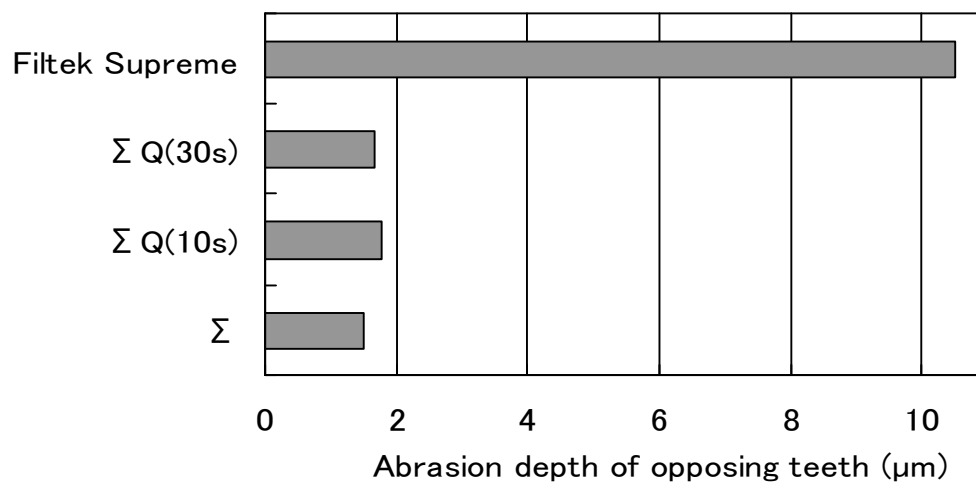


Fig. 16 Abrasion depth of opposing teeth (μm)

### 3.2.4. Flexural strength

Figure 17 presents the flexural strength of Estelite®  $\Sigma$  Quick and other commercially available composite resins.

The flexural strength of Estelite®  $\Sigma$  Quick is equivalent to that of Estelite®  $\Sigma$  and ranks as average among commercially available composite resins.

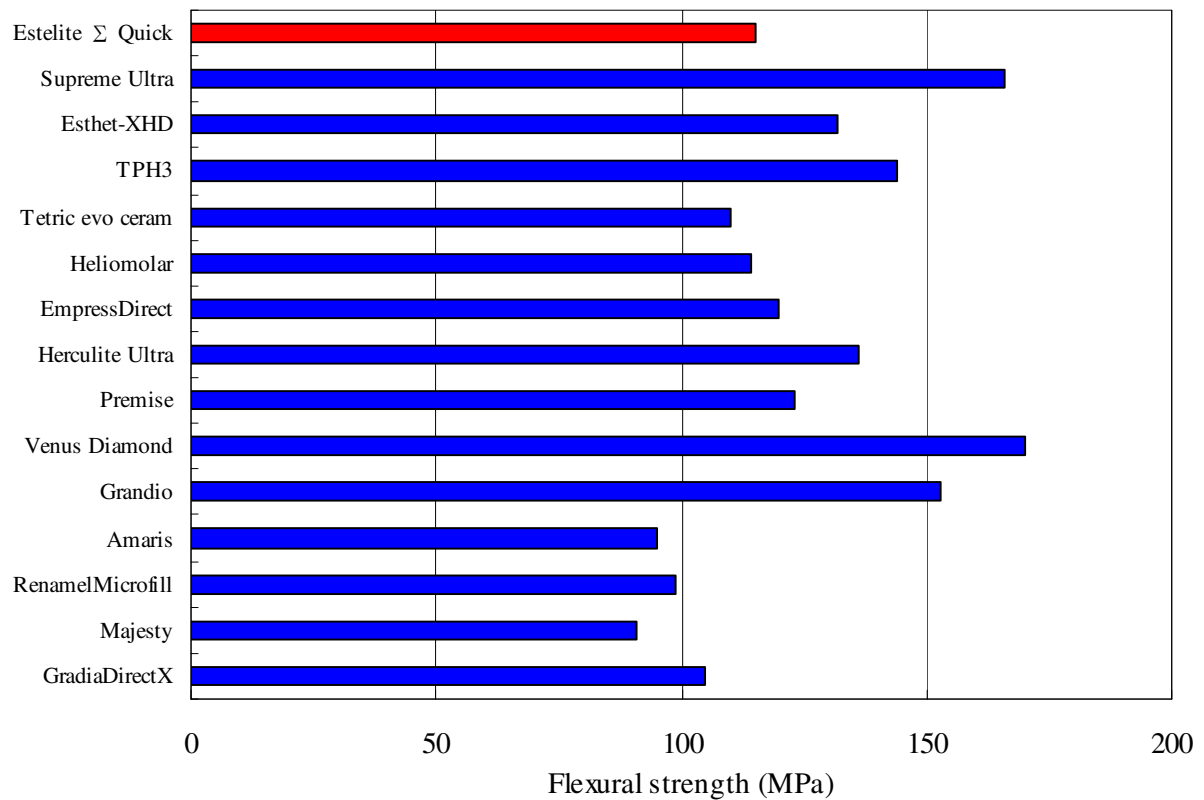


Fig. 17 Flexural strength

### 3.3. Esthetics

Estelite®  $\Sigma$  Quick readily produces a high gloss with relatively little polishing, since it uses the supra-nano spherical filler. In addition, as with Estelite®  $\Sigma$ , changes in color and translucency before and after polymerization are extremely low, the lowest among existing composite resins. Since Estelite®  $\Sigma$  Quick features high polymerization rate, it resists absorbing stains from substances such as coffee better than conventional products. We offer a wide range of shades in this line, including WE (White Enamel), which is useful for teeth after whitening, and OPA2, which features increased opacity, as well as the shade line of Estelite®  $\Sigma$  (18 shades). Offering a total of 20 shades, Estelite®  $\Sigma$  Quick is suitable for use in a wide range of clinical cases.

#### 3.3.1. Shade (color matching)

As shown in Figure 18, Estelite®  $\Sigma$  Quick offers 20 shades including 3 different hue(A, B and C), several chroma and 4 different opacities(enamel, standard, opalescent and opaque shade). Opalescent shades (OA1, OA2, OA3) have adequate opacity designed for blocking out the dark shine that comes through the oral cavity (Class III and Class IV restorations). Opaque shade (OPA2) is designed for masking slight stain or reconstructing a highly opaque tooth (use as a thin layer at the lingual cavity wall of class III and IV). Estelite®  $\Sigma$  Quick is basically designed to make it possible that most cases can be restored by limited mono shade thorough its excellent shade matching/color blending effect (Figure 19). Besides, with some shade having 4 different opacity (Figure 20), Estelite®  $\Sigma$  Quick allows the highly esthetic restorations which require multi-shade layering technique such as Class IV.



Fig. 18 Available shades of Estelite®  $\Sigma$  Quick

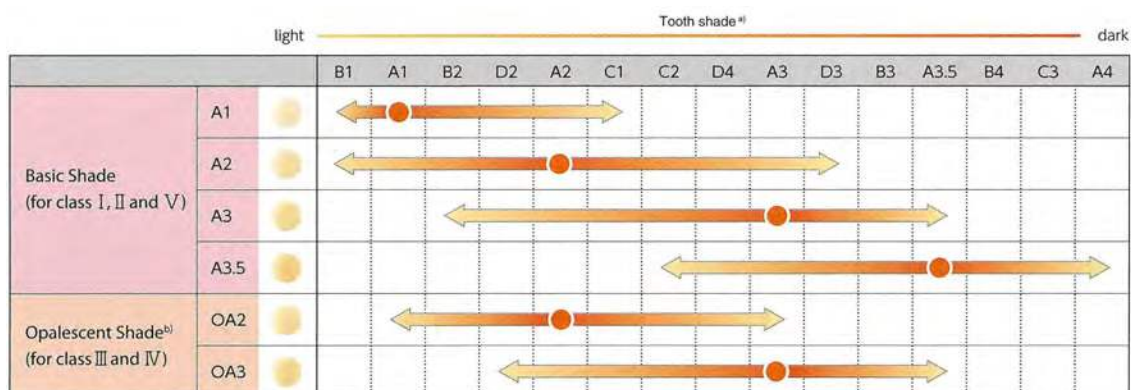
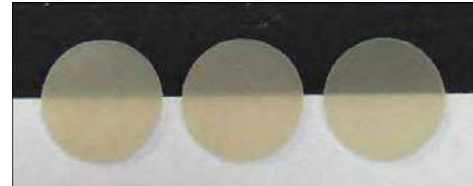


Fig. 19 Shade Matching Chart (Arrows indicate the range of tooth color the one resin shade can cover)



Estelite® Σ Quick A2 shade was filled in the center of each artificial teeth and shows excellent blending effect.

| Shade                                       | Contrast ratio*<br>(Yb/Yw) |
|---|----------------------------|
| Enamel Shade (CE, WE)                       | 0.45                       |
| Standard shade<br>(A1, A2,...except for CE) | 0.55                       |
| Opalescent shade (OA shade)                 | 0.65                       |
| Opaque shade (OPA2)                         | 0.75                       |



OPA2      OA2      A2  
0.75      0.65      0.55

\*The closer the contrast ratio (black back / white back) comes to 1, the shade comes to more opacous

Fig. 20 Contrast ratio (white back and black back) of Each shade

### 3.3.2. Surface gloss

Figure 21 shows surface gloss after the surface of cured CR is polished with waterproof abrasive paper (#1500) followed by Soflex super fine (for 60 seconds under running water). Figure 12 shows the relationship between polishing time and surface gloss. The results show that like Estelite® Σ, Estelite® Σ Quick produces extremely high gloss in short polishing sessions.

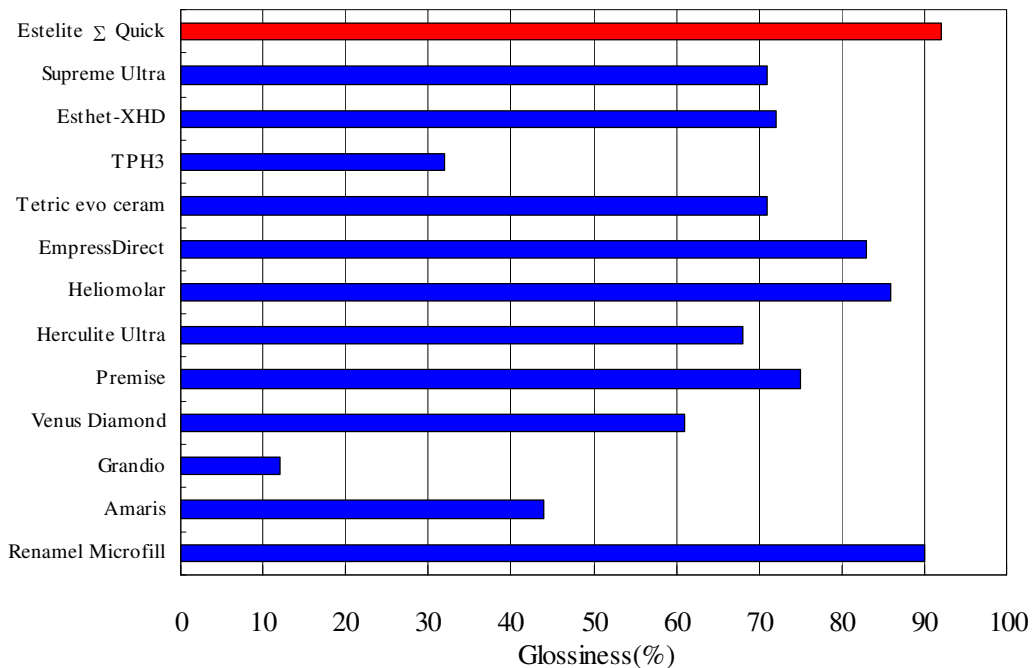


Fig.21 Surface Glossiness

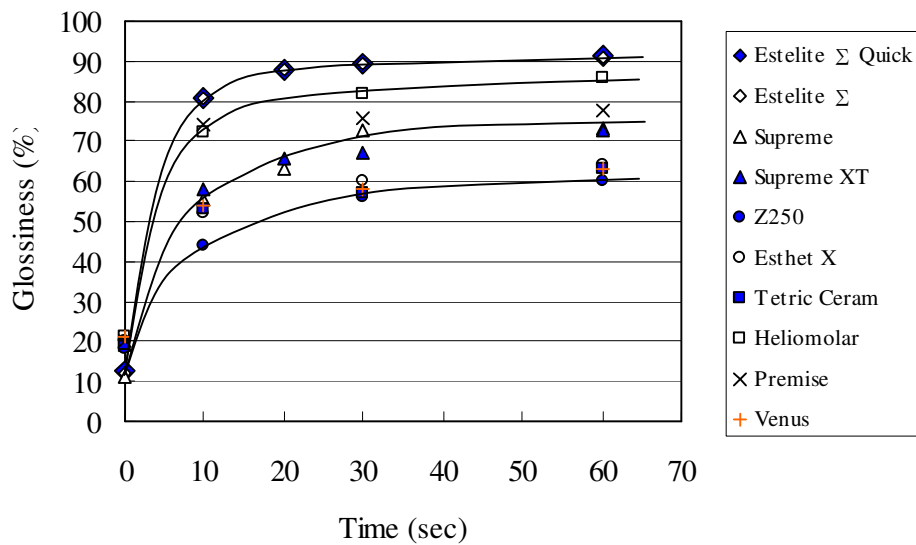


Fig.22 Relationship between glossiness and polishing time (Soflex super fine)

In addition to exhibiting extremely high gloss with relatively short polishing, Estelite® Σ Quick features a remarkably persistent gloss, based on results reported by the Department of Operative Dentistry at the Nihon University School of Dentistry.<sup>4)</sup> As Figure 23 shows, the high gloss of Estelite® Σ Quick directly after polishing persists even when subjected to repeated thermal cycles (5 degrees Celsius and 55 degrees Celsius).

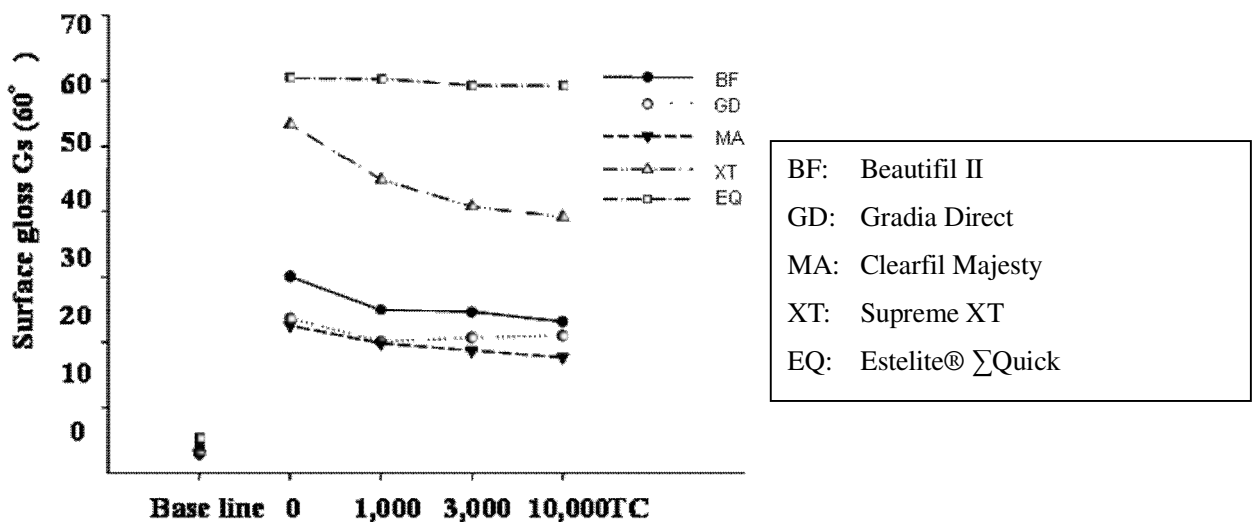


Fig.23 Gloss retention

Figure 24 shows 3D-images of the surface of cured resin after 50,000 times thermal cycle test. These pictures show that Etelite®  $\Sigma$  Quick keeps its surface smoothness, resulting in glossiness over time (self-shining effect).<sup>7) 8)</sup>

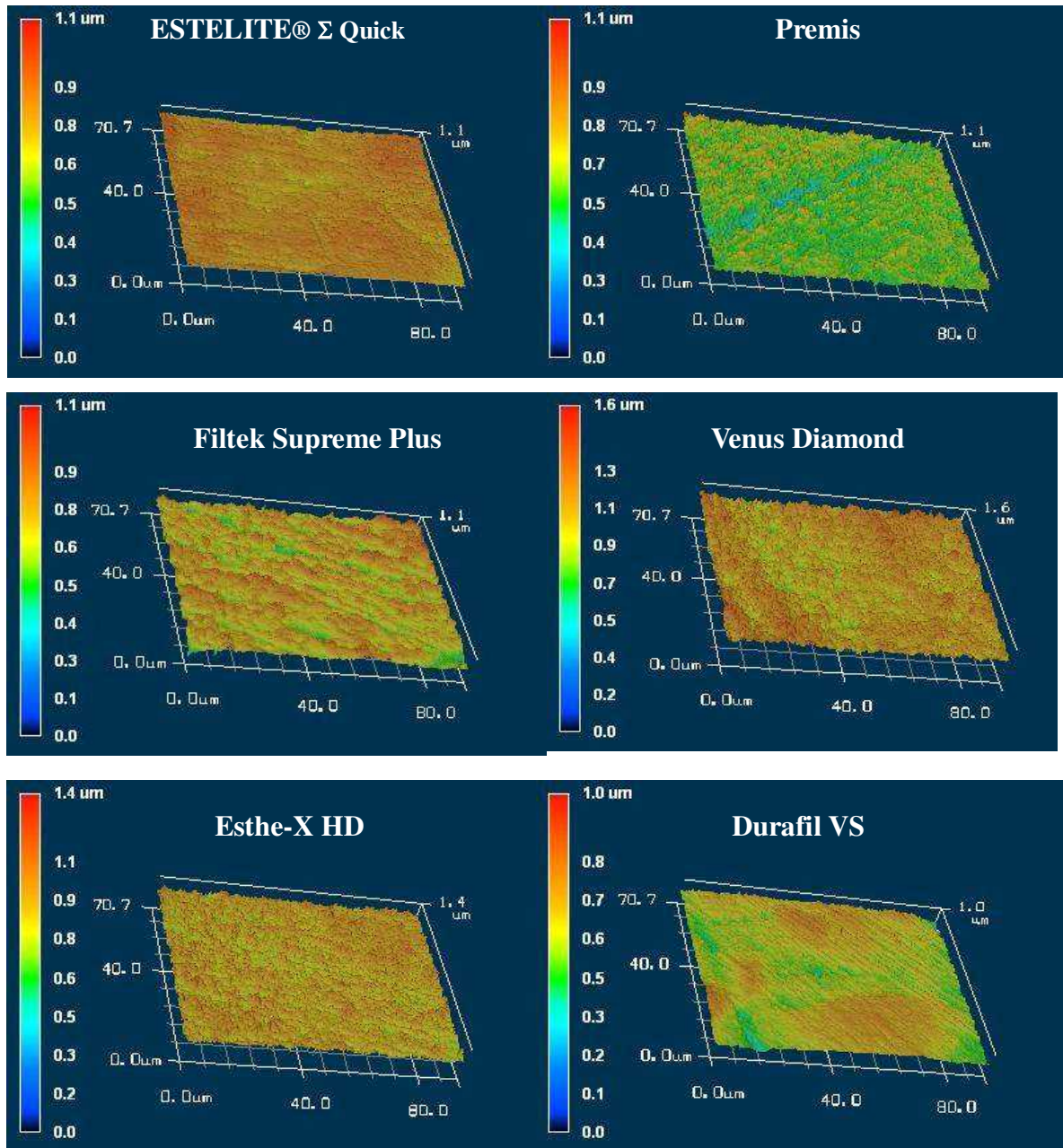


Fig.24 3D images of the surface of cured resin after thermal cycle test (50,000times)

### 3.3.3. Changes in color and translucency before and after polymerization

With respect to the shade matching of a composite resin, a resin associated with significant color changes before and after polymerization can present significant restoration issues for color matching, since the actual tooth and the resin cannot be assessed before polymerization. If the color of the composite resin fails to match the color of the tooth substance, the filling must be

removed and refilled, a labor-intensive procedure.

Estelite®  $\Sigma$  Quick features relatively low changes in color and translucency before and after polymerization, permitting rough color matching before polymerization. Figures 25 and 26 show the changes in color and translucency for Estelite®  $\Sigma$  Quick and other commercially available composite resins.

As indicated in the figures, Estelite®  $\Sigma$  Quick offers low change in both color and translucency, making shade-matching for Estelite®  $\Sigma$  Quick especially easy. Estelite®  $\Sigma$  Quick can reduce failures caused by colors that diverge significantly after curing.

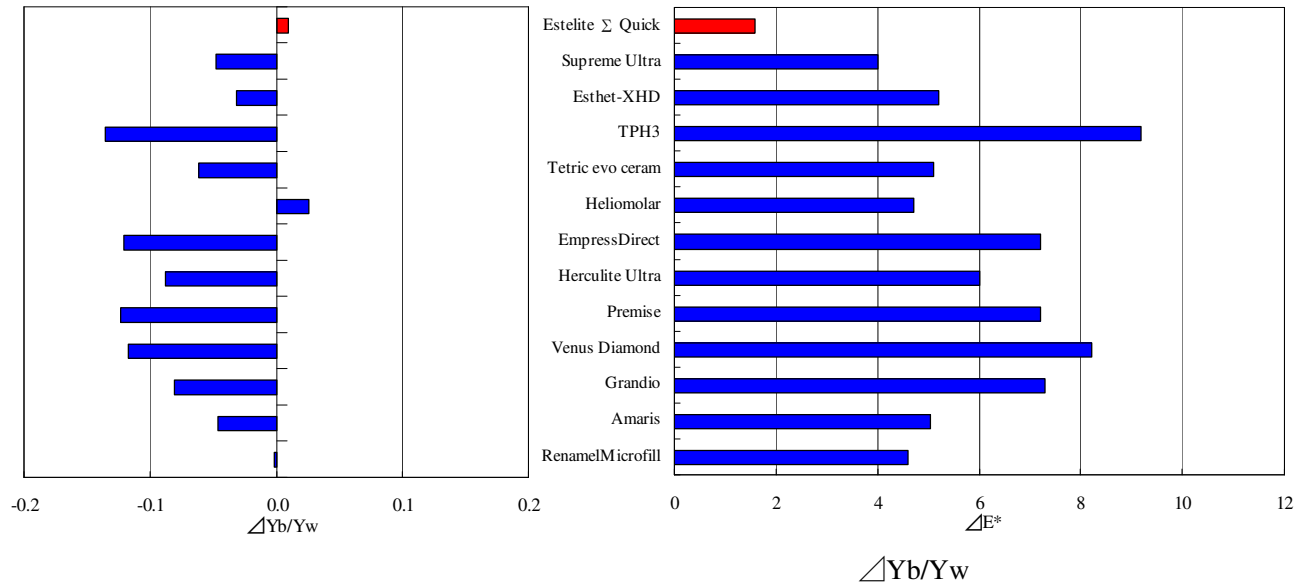


Fig.25 Color change ( $\Delta Yb/Yw$ ) and translucency change( $\Delta E^*$ ) before and after polymerization

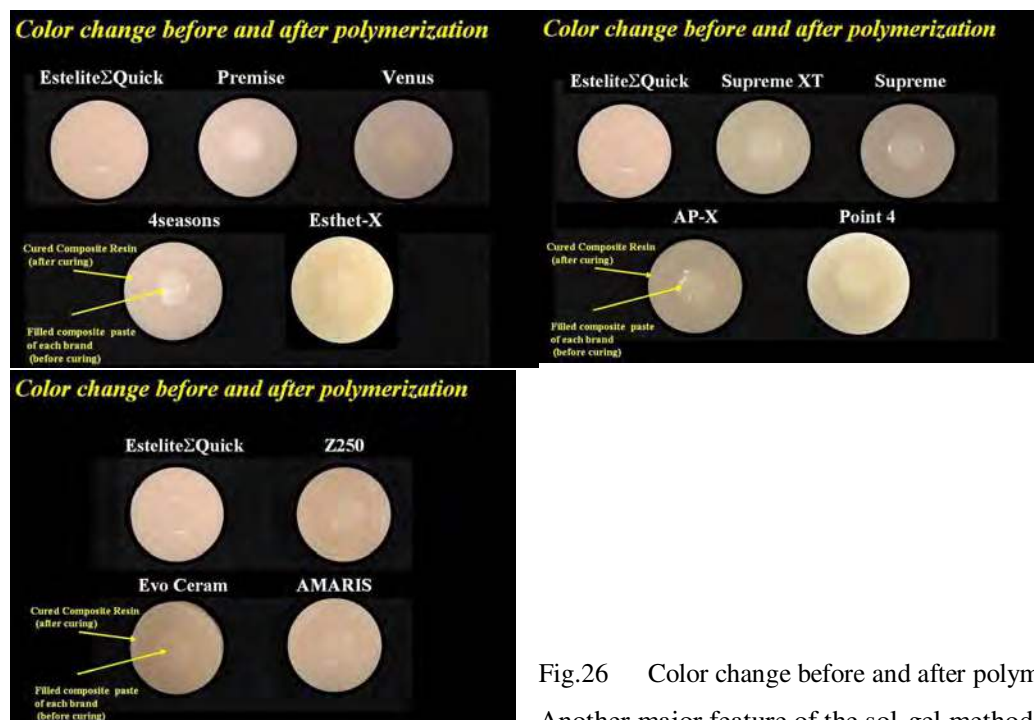


Fig.26 Color change before and after polymerization  
Another major feature of the sol-gel method is that

the refractive index of the filler can be controlled by changing the type and fraction of the additive. Composite resins tend to show a strong relationship between the filler refractive index and that of the matrix organic resin. To reproduce the semi-translucent quality of natural teeth using composite resins, we must control the difference between the refractive indices of the filler and the organic resin. Composite resins consist of fillers and organic resins containing catalysts. As shown in Figure 27, when the refractive indices of both materials are equal, the composite resin is highly translucent; when they differ significantly, the resin is opaque. The refractive index of resins tends to change from before to after polymerization; the refractive index of the cured resin (polymer) tends to be higher than that of the resin (monomer) before curing. To suppress changes in translucency from before to after polymerization, we must maintain the same difference between the refractive indices of the resin and filler from before to after polymerization. This means maintaining the refractive index of the filler close to the intermediate value of the refractive indices of the monomer and the polymer. In Estelite®  $\Sigma$  Quick, the silica/zirconia composition is adjusted to prepare fillers with optimal refractive indices.

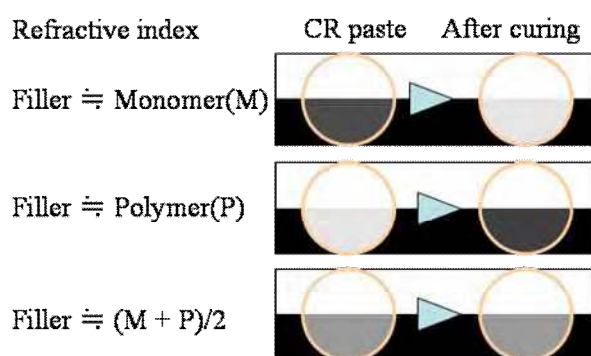


Fig.27 Relation between refractive index and opacity

### 3.3.4. Staining (e.g., by coffee)

A composite resin used in the oral cavity degrades over time due to exposure to various food and drink substances. If this change is pronounced relative to actual teeth, the effect is noticeable and unsightly. Here, we examined potential staining by coffee (24 hours soaking at 80 degrees Celsius). Figure 28 shows the results.

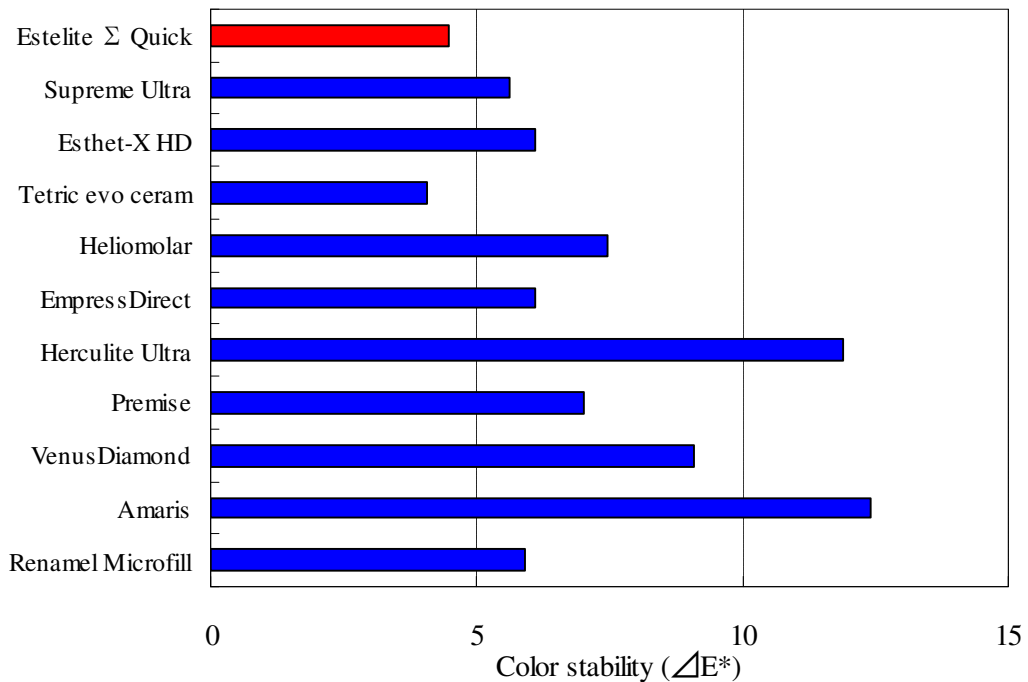


Fig.28 Color stability( $\Delta E^*$ )

The extent of staining for Estelite®  $\Sigma$  Quick after soaking in coffee was relatively low among commercially available composite resins. We believe Estelite®  $\Sigma$  Quick will retain its color at the time of restoration over a long term.

### 3.4. Ease of use

#### 3.4.1. Paste characteristics

Restoration with a composite resin requires reproducing the anatomical and occlusal form of the tooth. In these restorative operations, especially less stickiness and form retention of the paste are critical. Like Estelite®  $\Sigma$ , Estelite®  $\Sigma$  Quick exhibits less stickiness, good sculpting traits and can retain its form after forming. These paste characteristics can be obtained by our own technology of filler surface treatment to improve the compatibility between filler and monomer and other several unique technologies. The photographs below indicate the state of each resin after a cross is marked on 0.1 g of the paste with a instrument, after which the resin is allowed to stand for 30 minutes at 37 degrees Celsius (Figure 29).

As the photographs show, while the cross markings on the other commercially available resins shrink, Estelite®  $\Sigma$  Quick and Estelite®  $\Sigma$  retain their form for 30 minutes at 37 degrees Celsius. Clearly, Estelite®  $\Sigma$  Quick and Estelite®  $\Sigma$  are capable of reproducing the occlusal form.

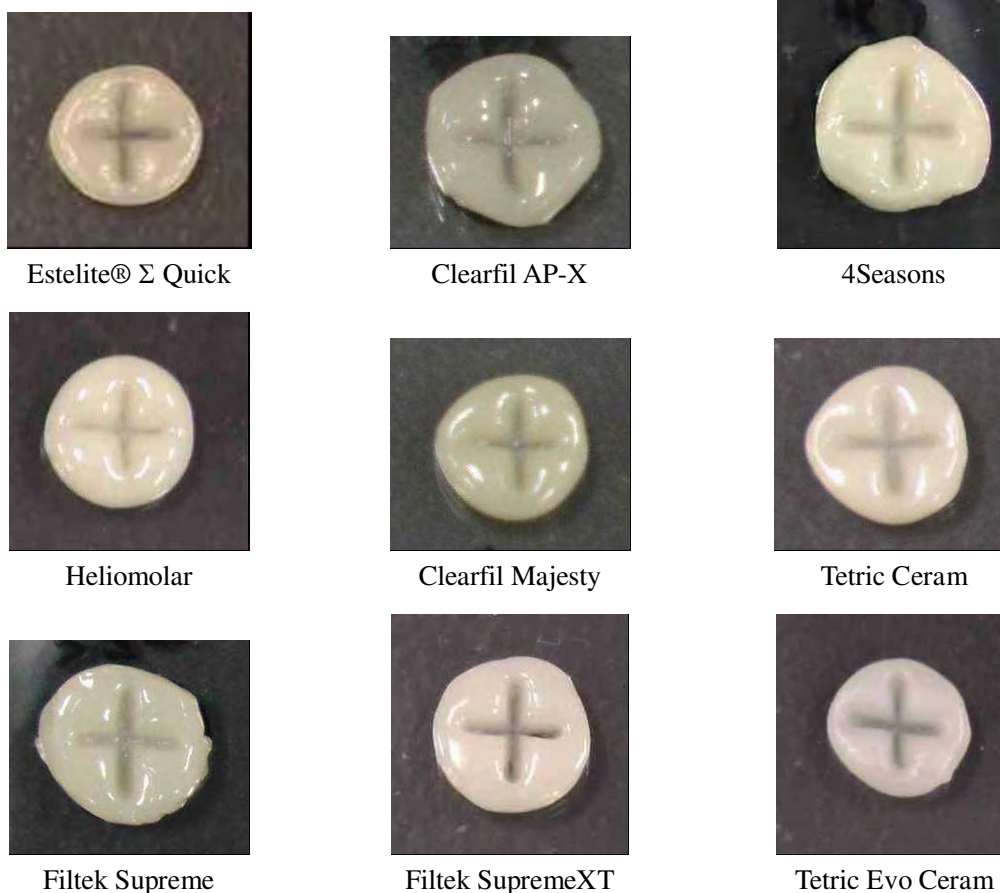


Fig.29 Paste state after 30 minutes at 37 degrees Celsius

## 4. Properties

Estelite® Σ Quick exhibits various outstanding properties as a dental restoration composite resin. Here, we describe its diffuse transmission and radiopacity.

### 4.1 Diffuse transmission

Color matching for a composite resin is influenced by diffuse transmission.<sup>5) 6)</sup> A composite resin with high diffuse transmission produces good color matching results, since diffuse transmission blurs the border between the composite resin and the actual tooth. Figure 30 shows evaluations of diffuse transmission for various composite resins. The evaluation method is as follows: Cured resin having a thickness of 0.3 mm is exposed to a laser pointer at a distance of 2 cm and the light transmitted through the cured resin observed. As Fig. 30 shows, the light source appears blurred through Estelite® Σ Quick, indicating light diffusion.

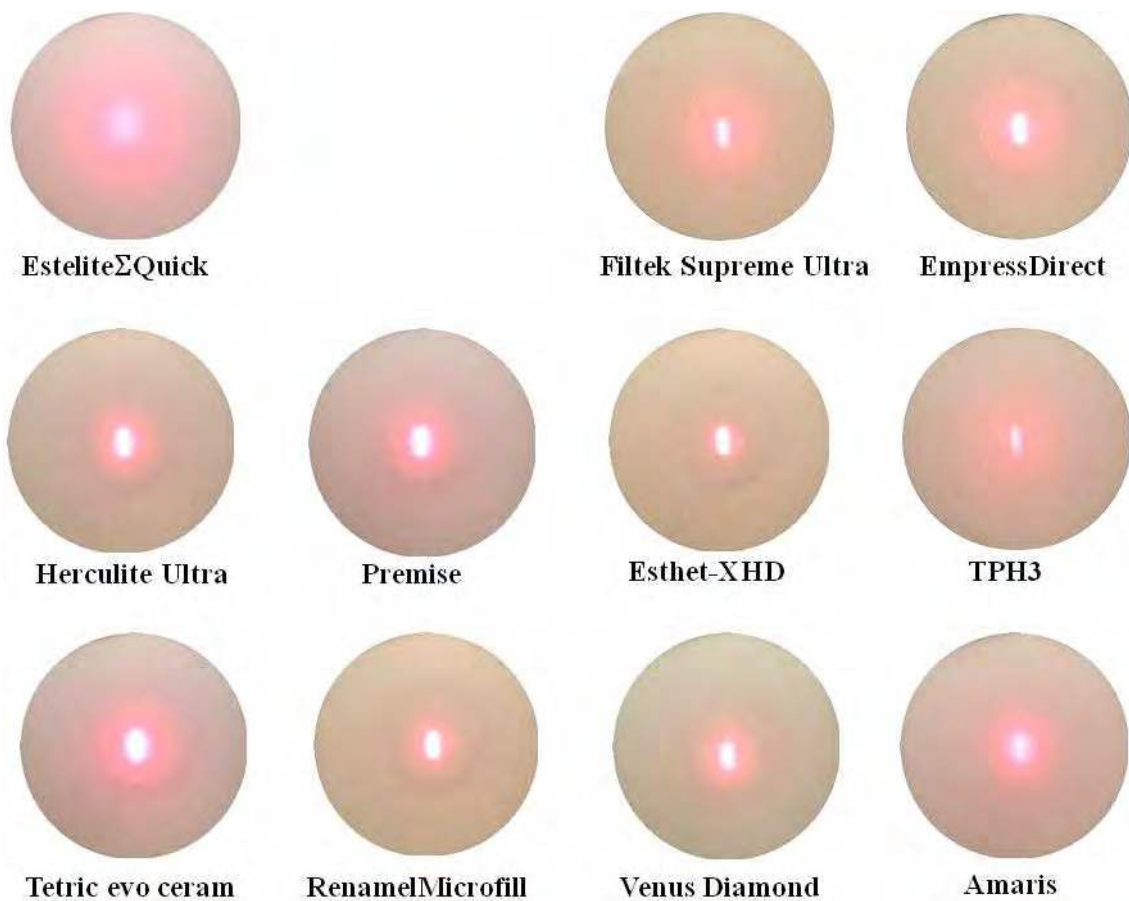
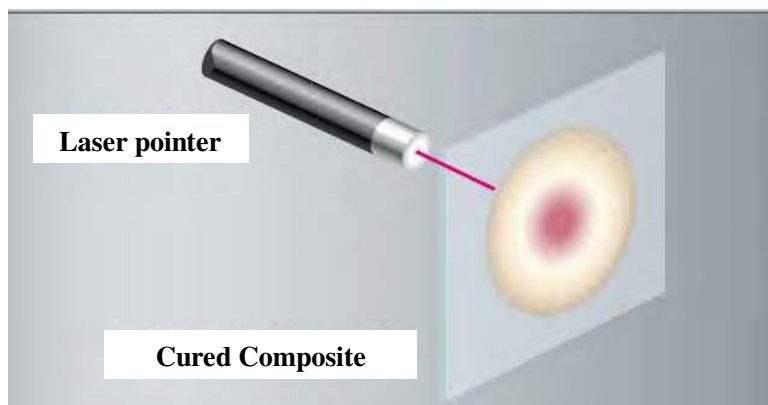


Fig.30 Diffuse transmission

## 4.2 Radiopacity

Radiopacity is determined by the composition of the inorganic filler and its filler content. The radiopacity of a resin is higher if the composition of the resin includes larger amount of elements with high atomic numbers at higher filler content. However, a filler containing large amounts of elements with high atomic numbers is associated with large refractive indices and significant changes in color and translucency before and after polymerization.

As indicated in 3.3.2, the inorganic filler used in Estelite®  $\Sigma$  Quick is designed to minimize changes in color and translucency from before to after polymerization and to maximize radiopacity under this constraint. Figure 31 shows the radiopacity of commercially-available composite resins.

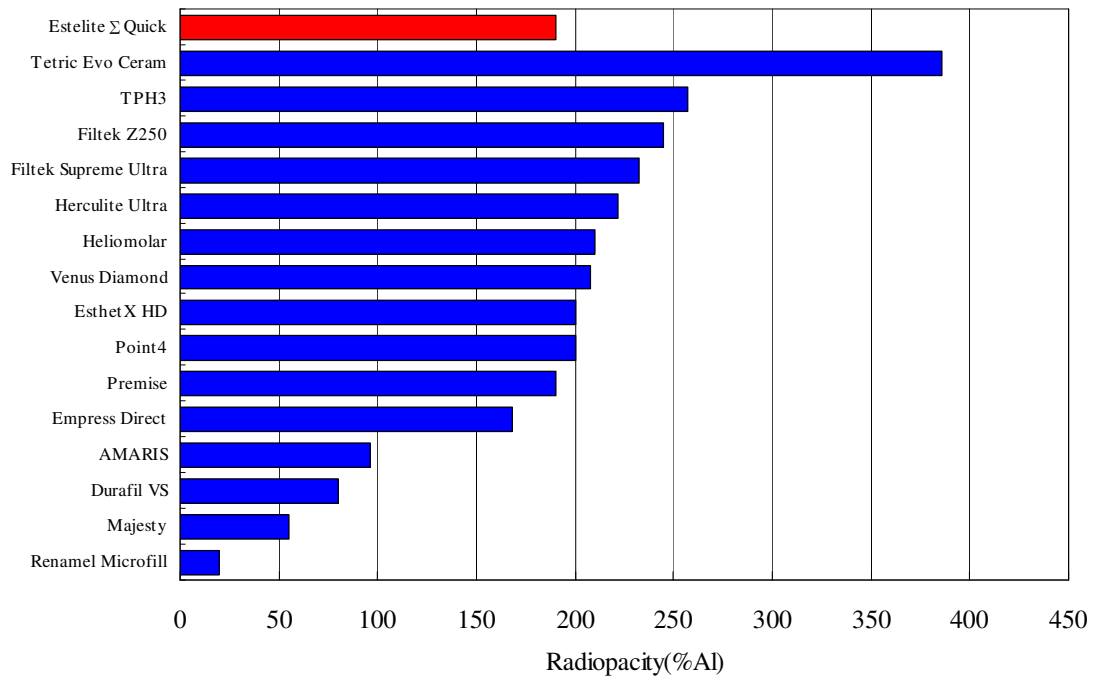


Fig.31 Radiopacity(%Al)

The radiopacity of Estelite®  $\Sigma$  Quick is slightly lower than comparable products. However, it meets the levels required to observe prognoses. The figure on the right is a clinical X-ray image of Estelite®  $\Sigma$  Quick.



## 5. Summary

Estelite®  $\Sigma$  Quick is a composite resin offering various outstanding traits, including desirable levels of polymerization activity and cosmetics thanks to the submicron monodispersing spherical filler and polymerization catalyst technology (RAP technology™) used in Estelite® Flow Quick.

### (1) Fast curing

- Estelite®  $\Sigma$  Quick cures in approximately 1/3 the exposure time required for conventional composite resins.
- Estelite®  $\Sigma$  Quick does not require a specific type of light source for the light-curing unit; it cures rapidly under halogen, LED, or Xenon light sources.
- Estelite®  $\Sigma$  Quick is less sensitive to ambient light than conventional products.

### (2) Outstanding scientific and engineering properties

- Estelite®  $\Sigma$  Quick features extremely low shrinkage, the lowest among commercially available composite resins.
- Estelite®  $\Sigma$  Quick offers superior characteristics with respect to wear resistance and opposing tooth wear.

### (3) Outstanding esthetics

- Estelite®  $\Sigma$  Quick provides high gloss with little polishing.
- Estelite®  $\Sigma$  Quick exhibits minimal changes in translucency and color from before to after polymerization.
- Estelite®  $\Sigma$  Quick is available in total of 20 shades, including a newly-added whitening optimized shade (WE: White Enamel)

### (4) Ease of use

- Readily sculpted

## 6. Frequently Asked Questions

Q1. Why can high glossiness be achieved with ease of polish?

A1. Because the inorganic, round shaped and very small fillers ( $0.2\ \mu\text{m}$ ) are dispersed in the paste evenly.

Q2. Why can its glossiness be retained for long?

A2. Even after some fillers were dropped off due to abrasion of the surface, unevenness of the surface will be retained minimum because the same reason as A1 above.

Q3. Is there any recommended polishing tool?

A3. Ease of polish is one of feature of Estelite® Sigma Quick so that most of commercially available tools can be used for polishing. Following brands are the tools we checked and make sure to work well: PoGo™ (DENTSPLY/Caulk), Sof-Lex™ (3M/SPE), Identoflex® HiLuster Dia Polishers (Kerr), or D-FINETM Hybrid Diamond (COSMEDENT, Inc.)

Q4. Can I use Estelite® Sigma Quick for posterior restorations as well as anterior?

A4. Yes. Estelite Sigma Quick has superior esthetics for anterior restorations as well as adequate properties for posterior restorations in terms of fracture toughness, flexural strength, shrinkage and wear properties.

Q5. What is fracture toughness?

A5. It is the ability of material having a small crack to resist fracture. Generally, fracture toughness of human enamel is  $0.7 \sim 1.3\ \text{MPam}^{1/2}$ , that of human dentin is  $2.7 \sim 3.1\ \text{MPam}^{1/2}$ . Fracture toughness of Estelite Sigma Quick is  $1.79\ \text{MPam}^{1/2}$ .

Q6. Why can Estelite Sigma Quick blend with surrounded teeth well?

A6. Because the marginal line is getting vague thanks to its higher diffuse transmission and its glossiness which are close to natural teeth,

Q7. What is clinical advantage of low shrinkage?

A7. Lower shrinkage contributes to reduce the risk of gap and chipping occurrence between composite and teeth.

Q8. How depth is recommended for each one layer in case that incremental filling is required?

A8. Do not exceed the depth indicated in IFU. (e.g. 2.0 mm in case of A3 shade irradiated by LED for 10 sec. This depth is clinical figure, which is 1/2 of curing depth in vitro, calculated in accordance with ISO 4049: 2000.)

Q9. Is there any recommended light unit?


A9. You can use any conventional light units having a wavelength range of 400 to 500nm (peak: 470nm), which is absorption spectrum of camphorquinone contained in Estelite® Sigma Quick as photoinitiator.

## 7. References

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DE, No. 128, 33-36 (1999)
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- 4) Hiroyasu Kurokawa, et al., “Temporal change of polished surface of composite resin,” Japanese journal of conservative dentistry, 50 (Autumn special issue), 17, 2007
- 5) Shigehisa Inokoshi, “Pursuing color matching of crown-color fillers,” Dental Outlook, vol. 88, No. 4, 785-821, 1996
- 6) Shigehisa Inokoshi, “Color of composite resin filling — opacity and light diffusion properties,” DE, No.163, 5-8, 2007
- 7) Steven Armstrong, et al., “Evaluate polishability and gloss retention of nano filled resin-based composites (RBC) after thermocycling”, Oral Session, IADR San Diego, 2011
- 8) Saulo Geraldelli, et al., “Polishability of Nanofilled Resin-based Composites”, ADM, 2010

## Appendix-1

### **Estelite Product Range and Recommended Indications**

| Indication                    | Criteria  | Universal Composite   | Posterior Composite  | Flowable Composite  |   |
|-------------------------------|-----------|---|--|---|---|
|                               |           |  |  |  |  |
|                               |           | Estelite® Sigma Quick   | Estelite® Posterior  | Estelite® Flow Quick  | Estelite® Flow Quick High Flow  |
| Class I & II                  | Strength  | Very Good   | Excellent  | -   | -   |
|                               | Esthetics | Excellent   | Very Good  | -   | -   |
| Class III                     | Esthetics | Excellent   | Good   | Excellent   | Excellent   |
| Class IV                      | Esthetics | Excellent   | Good   | -   | -   |
| Class V                       | Esthetics | Excellent   | Good   | Excellent   | Excellent   |
| Small Cavity                  | Handling  | -   | -  | Excellent   | Excellent   |
| Cavity Lining, Shallow Cavity | Handling  | -   | -  | Very Good   | Excellent   |
| Radiopacity                   |           | YES   | YES  | YES   | YES   |
| Light Cure                    |           | YES   | YES  | YES   | YES   |

**Physical Properties**

| Properties                 |                 | ESTELITE®<br>SIGMA<br>QUICK | Filetek™<br>Supreme<br>Ultra<br>(body) | Filetek™<br>Supreme<br>XT<br>(body) | Esthet X<br>HD | TPH3®  | Tetric<br>EvoCeram® | Venus<br>Diamond® | Premise™ | Herculite®<br>Ultra | Gradia<br>Direct X™ | Grandio® |
|----------------------------|-----------------|-----------------------------|--|-------------------------------------|----------------|--------|---------------------|-------------------|----------|---------------------|---------------------|----------|
| shade variety              |                 | 20                          | 36                                     | 35                                  | 31             | 29     | 19                  | 23                | 30       | 10                  | 11                  | 16       |
| flexural strength          | MPa             | 115                         | 166                                    | 159                                 | 132            | 144    | 110                 | 170               | 123      | 136                 | 105                 | 153      |
| flexural modulus           | GPa             | 8.7                         | 13.2                                   | 14.2                                | 10.8           | 11.7   | 10.7                | 14.1              | 9.8      | 10.0                | 7.2                 | 19.5     |
| compressive strength       | MPa             | 400                         | 463                                    | 447                                 | 436            | 391    | 367                 | 399               | 397      | 408                 | 320                 | 358      |
| shrinkage*                 | linear %        | 1.3                         | 1.2                                    | 1.4                                 | 1.9            | 2.1    | 1.3                 | 1.4               | 1.3      | 1.9                 | 1.7                 | 1.3      |
| working time*              | sec             | 90                          | 90                                     | 55                                  | 40             | 25     | 75                  | 125               | 40       | 50                  | 60                  | 30       |
| color change*              | dE*             | 1.6                         | 4.0                                    | 5.8                                 | 5.2            | 9.2    | 5.1                 | 8.2               | 7.2      | 6.0                 | 9.5                 | 7.3      |
| translucency change*       | dYb/Yw          | 0.010                       | -0.047                                 | -0.080                              | -0.031         | -0.136 | -0.061              | -0.118            | -0.123   | -0.088              | -0.154              | -0.081   |
| gloss*                     | %               | 91                          | 71                                     | 70                                  | 72             | 32     | 71                  | 61                | 75       | 68                  | 67                  | 12       |
| color stability*           | dE*             | 4.5                         | 5.6                                    | N/A                                 | 6.1            | N/A    | 4.1                 | 5.5               | 7.0      | 11.9                | 9.2                 | N/A      |
| radiopacity                | Al%             | 190                         | 232                                    | N/A                                 | 200            | 257    | 386                 | 208               | 190      | 221                 | N/A                 | N/A      |
| wear                       | mm <sup>3</sup> | 0.0032                      | 0.083                                  | 0.0751                              | N/A            | 0.0277 | 0.0316              | N/A               | 0.0147   | N/A                 | N/A                 | 0.0635   |
| abrasion of opposing teeth | µm              | 0.47                        | 16.17                                  | 14.89                               | N/A            | 2.83   | 3.79                | N/A               | 3.4      | N/A                 | N/A                 | 7.24     |

Source: Tokuyama Dental R&amp;D

\*shrinkage: linear %

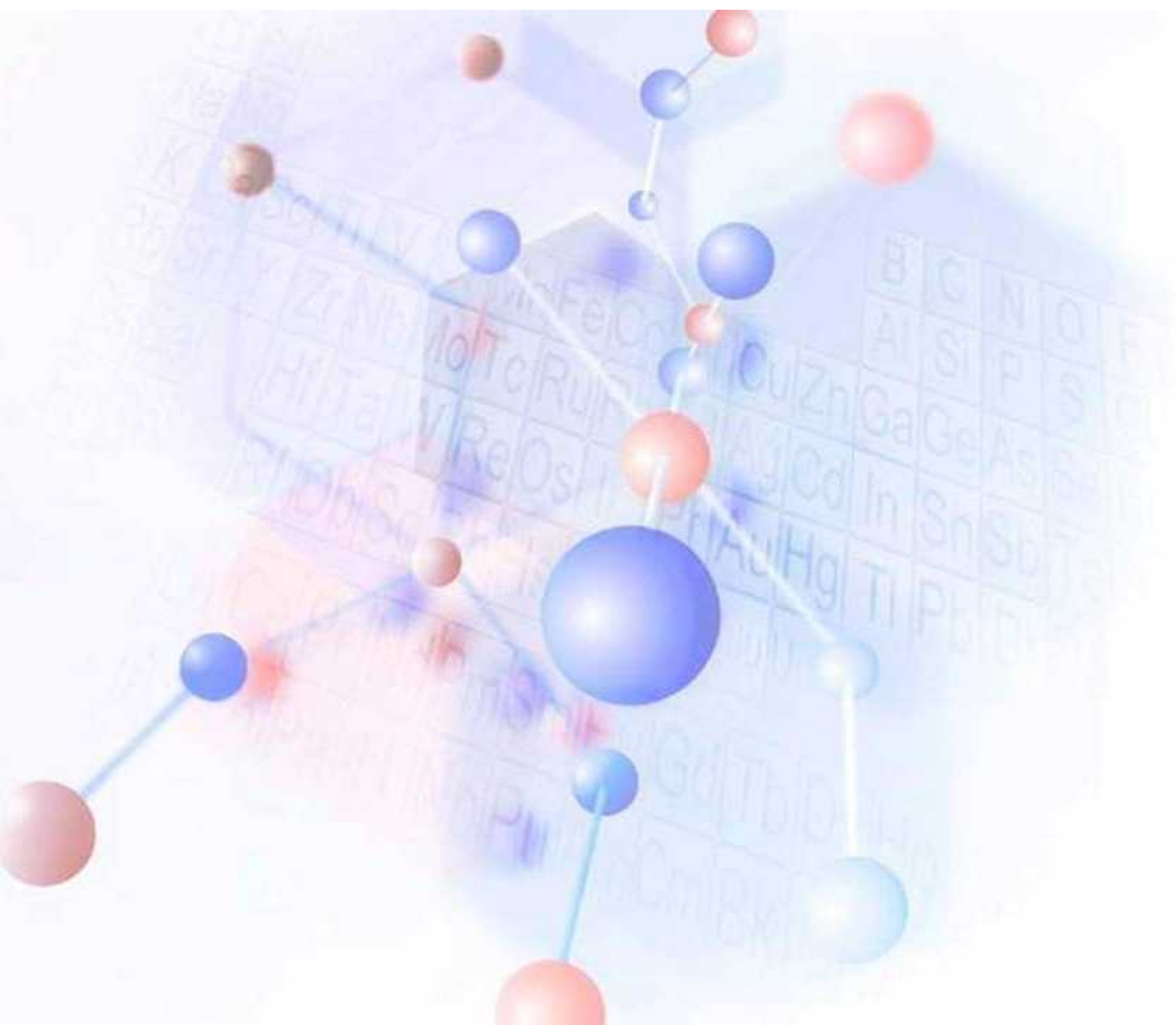
\*working time: under dental light (10,000LUX)

\*color change: color change before and after polymerization

\* translucency change: translucency before and after polymerization

\*gloss: after 60 sec. polished by Sof-Lex™ superfine

\*color stability: after stored in coffee (7.4%) at 80°C for 24 hours



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