Clinical Study of the Color Stability of Veneering Ceramics for Zirconia Frameworks

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Purpose: The purpose of this study was to compare 3 veneering ceramics for zirconia frameworks regarding color stability and predictability of the esthetic result. ***Materials and Methods****:* Six patients with 1 maxillary central incisor to be restored were enrolled in the study. The contralateral incisor had to be nonrestored and vital to serve as a reference tooth. For each patient, 4 single crowns with zirconia frameworks were fabricated. Three veneering ceramics were assessed and masked to eliminate bias. Choice of the veneering ceramics was done at random. The veneering was performed by 4 dental technicians. Three veneering ceramics were compared: ceramic A (Initial, GC), ceramic B (Triceram, Esprident), and ceramic C (Cercon Ceram S, DeguDent). The color of the crowns and reference teeth was captured using spectrophotometric analysis (SpectroShade, MHT), and the color difference (ΔE) was calculated (objective method). In addition, the crowns and reference teeth were compared subjectively by 11 observers blind to the ceramic used for veneering. Statistical analysis was performed with analysis of variance (ANOVA). ***Results:*** Regardless of the veneering ceramic used, all crowns showed a high color deviation from the reference teeth when applying the objective analysis (ΔE_A 6.8 ± 2.5, ΔE_B 5.6 ± 1.2, ΔE_C 5.7 ± 2.1). In addition, no significant differences were found between the ΔE of crowns and teeth for the 3 ceramics. In the framework-supported area, ceramic B showed a significantly lower difference in value (ΔL) compared to the reference teeth than the other 2 ceramics (ΔL_A 4.9 ± 2.3, ΔL_B 1.1 ± 2.1, ΔL_C 4.1 ± 1.5; $P < .01$ ANOVA). When performing the subjective analysis, ceramic B was chosen as the best match by a majority of observers (> 60%) in 4 of 6 patients. ***Conclusions:*** All 3 ceramics met the esthetic demands only to a limited extent. Ceramic B allowed for the most predictable result in terms of color stability. *Int J Prosthodont 2007;20:263–269.*

When fabricating metal-ceramic restorations, the gray metal framework makes it difficult to imitate natural esthetics. This is particularly true in situations with limited space for the restoration. The advantage of all-ceramic restorations compared to metal-ceramic restorations is their excellent ability to obtain optimal esthetic outcomes. However, because of their low mechanical stability, all-ceramic systems (feldspathic-reinforced, glass-reinforced, and glass ceramics) have only been demonstrated to be suitable for single crowns. All-ceramic fixed partial dentures (FPDs) showed high fracture rates in both anterior and posterior areas.[1–4] More recently, high-strength ceramics with mechanical characteristics superior to those of conventional ceramics have been developed for reconstructive dentistry. Zirconia, the most stable of these high-strength ceramics, has flexural strength and fracture toughness values of 900 MPa and 9 MPa $m^{1/2}$, respectively.[5–7] These values are twice as high as those of glass ceramics and glass-infiltrated alumina.[1,2] In medium-term clinical studies, high success rates for reconstructions with zirconia frameworks in anterior

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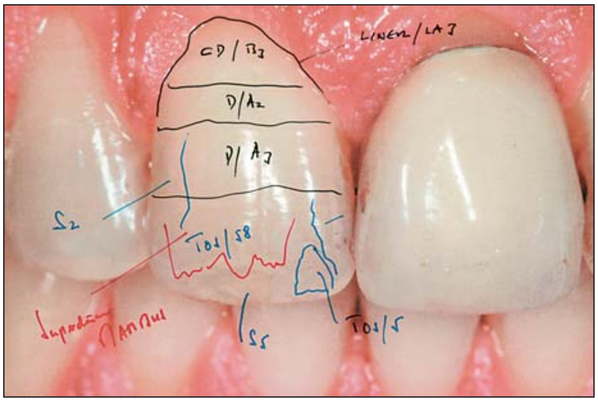

Fig 1 Enlarged photograph with the consensus shade prescription for one of the veneering ceramics. The locations and names of the desired shades for each of the ceramics were drawn on a transparent foil that could be positioned over the photograph.

and posterior areas have been observed. Three years after insertion, none of the examined posterior zirconia FPDs showed fractures of the framework.[8,9] These encouraging clinical results have led to an increasingly wide application of this type of ceramic restoration. Zirconia is an opaque ceramic material exhibiting a white color, and is, therefore, only suitable as a framework material. Further, it must be veneered for optimal esthetic outcomes. As a result of its lower coefficient of thermal expansion (CTE $= 11 \times 10^{-6}K^{-1}$), traditional feldspathic ceramic cannot be used to veneer zirconia frameworks. Instead, a material with a CTE in the range of $13 \times 10^{-6} K^{-1}$ to $15 \times 10^{-6} K^{-1}$ is needed.[10] Thus, numerous new veneering ceramics specifically adapted to zirconia have been developed.

Today's veneering ceramics for metal frameworks are the result of decades of development. This development has compensated for the grayish color of the framework and enables excellent esthetic results. The development of veneering ceramics specifically adapted to zirconia is only in its pioneering stages. Nevertheless, to be suitable for clinical use in esthetic situations, veneered crowns with zirconia frameworks must achieve results similar to those with metal frameworks (the gold standard). The dental technician working with zirconia is faced with the new challenge of adapting a white framework instead of a gray framework.

The color of the restoration in relation to the neighboring teeth is one of the main factors determining the esthetic outcome. The color is influenced by a number of factors. Most important in this context is the selection of the correct shade or mixture of shades. In addition, the layering technique and the thickness of the veneering layer introduce effects that further influence color. Finally, adjustments of the furnace (changes in baking temperature/holding time) can help obtain desired color changes.[11] Different veneering ceramics require several different methods to influence the color by controlling the forementioned factors. Hence, the quality of a veneering ceramic is also dependent on whether the desired esthetic result can successfully be accomplished in an easy and reproducible way.

The aim of this study was to examine the color stability and technical processing tolerances of 3 veneering ceramics for zirconia frameworks.

Materials and Methods

Six patients with 1 maxillary central incisor to be restored were enrolled in the study. The contralateral reference incisor had to be nonrestored and vital. The requirements of the Helsinki Declaration were fulfilled and patients provided written consent.

Three veneering ceramics were compared:

- Ceramic A: Initial (GC Europe)
- Ceramic B: Triceram (Esprident)
- Ceramic C: Cercon Ceram S (DeguDent)

The ceramic powders were masked by transferring them into neutral glass containers labeled A, B, or C. Four dental technicians participated in the study. All 4 performed the clinical color selection together for the 6 patients using the VITA Classic shade guide (Vita Zahnfabrik). Additionally, the manufacturer-specific color patterns of the 3 ceramics were used. These were glued to neutral acrylic holders marked with A, B, or C, and thus masked as well.

The colors were determined for each of the 3 ceramics by obtaining a consensus shade prescription per tooth. Pretreatment intraoral photographs of all maxillary incisors were taken. These photographs were enlarged and the consensus shade prescription for each of the ceramics was written on a transparent removable foil. These foils could be positioned over the photographs (Fig 1) and used as the reference for veneering each of the crowns.

The veneering process of the crowns required only the preselected shades to be used. For standardization, no mixing of the ceramic powders was done to adjust the shades.

Each technician made 1 crown per patient, meaning a total of 24 crowns were evaluated (Table 1). The veneering ceramics were randomly chosen. Each technician manufactured 2 crowns with each of the veneering ceramics. As a result, 8 crowns for each veneering ceramic were available for evaluation.

Clinical and Laboratory Procedures

Two experienced prosthodontists prepared the incisors for the zirconia restorations. Each preparation had a

Table 1 Randomization of the Patients, Ceramics, and Dental Technicians

	Technician			
	1	2	3	4
Patient 1	Ceramic B	Ceramic C	Ceramic A	Ceramic C
Patient 2	Ceramic B	Ceramic C	Ceramic A	Ceramic C
Patient 3	Ceramic C	Ceramic A	Ceramic B	Ceramic A
Patient 4	Ceramic C	Ceramic A	Ceramic B	Ceramic B
Patient 5	Ceramic A	Ceramic B	Ceramic C	Ceramic A
Patient 6	Ceramic A	Ceramic B	Ceramic C	Ceramic B

Fig 2 The information and materials provided to the technicians for manufacturing of the crowns included masked shade guides and ceramic powders, a master cast and single stub, a 0.5-mm-thick zirconia coping, and a waxup of the desired tooth form.

1-mm-wide circumferential shoulder rounded on the inside. Two polyether impressions of the preparations were taken (Permadyne, 3M ESPE), and the opposing arch impression was taken using alginate. For each patient, 4 master casts and single stubs were fabricated. One waxup of the crown and 4 identical zirconia frameworks with a wall thickness of 0.5 mm were constructed (Cercon, DeguDent). The shape of the waxup defined the form and thus the thickness of the crowns. This procedure allowed standardization of the crown form. This was done because defining the form of a reconstruction is of primary importance for the overall esthetic outcome.[12] Figure 2 shows the information and materials provided to the technicians for manufacturing the crowns.

Veneering and Firing Processes

To standardize the veneering process, the various steps of the layering technique (opaque firing, shoulder firing, dentin/enamel firing, and glaze firing) were performed according to a strict protocol. The protocol adhered to the manufacturer's recommendations for each ceramic.

Four new furnaces (Austromat N, Dekema) were calibrated for use in this study. The recommended baking procedures for each ceramic material were programmed before delivery of the furnaces to the dental technicians. The programs again were masked with A, B, or C. Changes of temperature or holding times were not possible.

The technicians were required to complete a questionnaire for each crown that subjectively assessed the details of the veneering process. With aid of this questionnaire, they judged the masking ability of the frame modifiers and the stability of the shoulder, dentin, and enamel ceramic masses during modeling and baking. Finally, they judged the quality of the baking result (shrinkage, color, degree of glazing, surface quality). For further details, see Sailer et al.[13]

Color Evaluation

Color assessment of the fabricated crowns was carried out during a clinical try-in appointment. Objective digital color assessment was obtained by spectrophotometry (SpectroShade, MHT). Eleven observers to whom the ceramic materials were masked completed the subjective evaluation (7 male dental clinicians and dental technicians and 4 female dental clinicians).

For the objective assessment, a color reading was obtained of the 4 crowns and reference tooth in each patient. The included software automatically quantified the data, giving the red-green (a^*) and yellow-blue (b^*) axis values and brightness (value, L^*). This enabled mathematical comparison between the colors of reference teeth and test crowns. For this purpose, the color difference (ΔE) was determined using the following formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ where ΔL^*, Δa^*, and Δb^* were the differences of the color parameters between test crowns and control teeth.

Each measurement was repeated 3 times and the average was taken for further analysis. The color difference (ΔE) was determined at 3 locations per tooth/crown: cervical, body, and incisal. The cervical

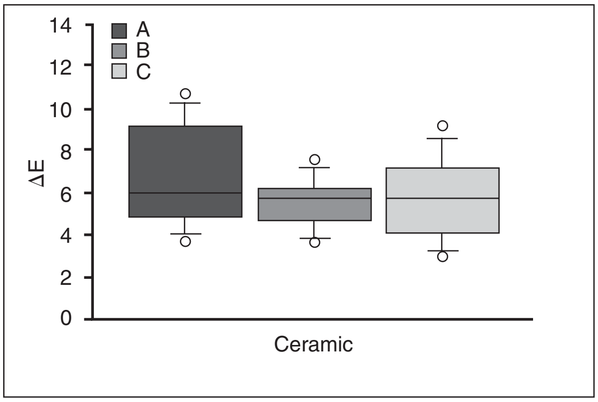

Fig 3 Mean color difference (ΔE) of ceramics A, B, and C compared to reference teeth.

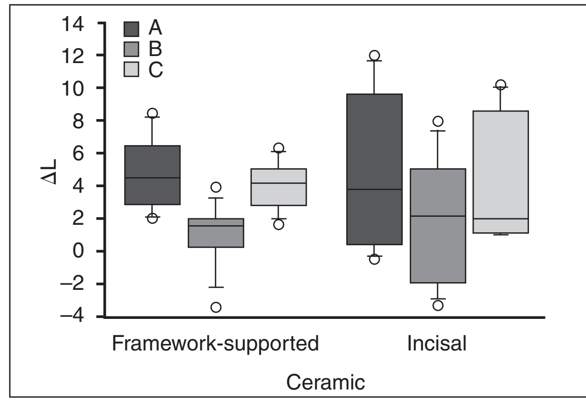

Fig 4 Mean difference in value (ΔL) of the crowns compared to the reference teeth. The color difference was evaluated for framework-supported and incisal areas.

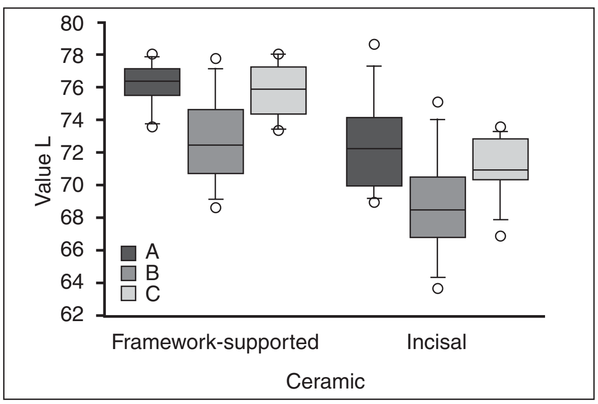

Fig 5 Overall mean value (L) of ceramics A, B, and C in the framework-supported and incisal regions.

and body measuring locations corresponded to the area of framework support, and the incisal measuring locations corresponds to the supporting framework. For the subjective assessment, the colors of the 4 crowns were compared with those of the reference teeth. The 11 observers ranked the 4 crowns for each patient on a scale from 1 to 4 under daylight conditions. The assessors also stated whether the best color match fulfilled clinical requirements.

Statistical Analysis

Descriptive statistics were used to evaluate the data of the questionnaire and subjective color assessment. Statistical analysis of the objective color evaluation was carried out by means of analysis of variance (ANOVA) with a level of significance set at $\alpha = .05$. Visualization of the data was performed using box plots.

Results

Objective Color Evaluation

All 3 ceramics showed a color deviation ($\Delta E\ MW_{czi}$) compared to the reference teeth. There were no significant differences among the 3 ceramics regarding these ΔE values (ΔE_A 6.79 ± 2.5, ΔE_B 5.56 ± 1.2, ΔE_C 5.73 ± 2.1) (Fig 3). In the framework-supported area of the crowns (cervical + body), ceramic B showed a significantly smaller difference regarding value (ΔL) compared to the reference teeth (ΔL_A 4.86 ± 2.3, ΔL_B 1.06 ± 2.1, ΔL_C 4.06 ± 1.5; $P < .01$ ANOVA) (Fig 4). In the incisal area (without framework support), ceramic B exhibited a smaller ΔL than the other ceramics. However, this difference was not statistically significant (ΔL_A 4.98 ± 4.9, ΔL_B 1.94 ± 4.1, ΔL_C 4.36 ± 4.1) (Fig 5). Ceramic B showed lower value (L) at both locations compared to the other 2 ceramics.

Subjective Color Evaluation

The subjective selections of the observers were quite heterogenic. In 4 of 6 patients, ceramic B was selected as the best match by a majority of observers (> 60%). In only 1 patient was this ceramic never chosen as the best match. Ceramic A was judged the best match in 2 patients. Ceramic C was never chosen as the best match by a majority of observers; however, in 3 patients it was selected as the best match by a minority of observers (36.4%, 27.3%, and 18.2%, respectively). In the other 3 patients, ceramic C was never preferred.

None of the ceramics were judged to be esthetically ideal. Of the 24 crowns, 16 were judged to be acceptable, 10 of which were veneered with ceramic B, 4 with ceramic A, and 2 with ceramic C (Figs 6 to 9). Thus, ceramic B clearly showed the best color results as judged objectively and subjectively.

Fig 6 The crown veneered with ceramic A was selected as the best match for patient 1.

Fig 7 Ceramic C exhibited extensive glazing, leading to higher L value in the framework-supported area and grayish discoloring of the incisal region.

Fig 8 The crown veneered with ceramic B was selected as the best match for patient 4.

Fig 9 For patient 4, the crown veneered with ceramic A did not match the reference because of extensive glazing and a subsequently high L value.

Ease of Processing

Ceramics A and B showed less pronounced form alterations during baking (more stability, less shrinkage) than ceramic C. Therefore, the desired result after baking was achieved in an easier and more predictable way using ceramics A and B.

In agreement with the subjective color evaluation, the analysis of the questionnaires filled out by the dental technicians revealed that the desired color results were most predictably achieved when using ceramic B. However, all 3 ceramics were subjected to a high degree of glazing.

Discussion

This is a descriptive study of a specific laboratory protocol and should serve as the starting point for using this methodology to compare other types of veneering ceramic techniques. As such, a control group for comparative purposes was not included in the research design; nor was statistical analysis performed. This apparent shortcoming will be addressed in subsequent papers from ongoing studies.

In the present study, color stability and technical processing tolerance of 3 established zirconia veneering ceramics were examined. The best and most predictable color results were achieved using ceramic B. Ceramic A reached the desired color result in only 2 of 6 patients by means of the standardized layering procedure. Ceramic C exhibited the least satisfactory color stability. It was seldom chosen as the best color match compared to the reference teeth.

None of the ceramics met the highest esthetic demands. This was demonstrated by the subjective analysis and the results of the spectrophotometric color measurements. The deviations were above the threshold for color difference visible by the naked eye under laboratory conditions ($\Delta E = 1$)[14] as well as under conditions normally encountered when judging crowns in the patient's mouth ($\Delta E = 3.7$).[15] Among the 3 ceramics, there were no significant differences regarding ΔE

compared to the reference teeth. The subjective evaluations performed by the observers judged half of the crowns as clinically acceptable. This indicates that the ΔE values mentioned above for judging colors under clinical conditions did not represent a clear-cut threshold for rendering a crown color unacceptable by the observers in the present study.

The assessment of color is influenced by 3 variables: shade (eg, red, orange, blue), saturation (chroma), and value (total reflection of light).[11] During the firing process, all zirconia veneering ceramics experienced a pronounced increase in translucency caused by strong glazing. With each firing step, the white color of the zirconia framework became more visible through the veneering ceramic, and thus led to an increase in value and opacity within the framework-supported area. Because of the resulting high opacity, the crowns lacked the optical "depth" characteristic of natural tooth substance. In the incisal area, where no framework support is present, the increased translucency led to a grayish discoloring.

The superior results obtained with ceramic B were a result of the high ability of the modifier to mask the framework and the lower tendency of this ceramic for glazing. These 2 factors reduced the negative influence of the white framework on the color of the veneered crown. In contrast to the other 2 ceramics, ceramic B offered a significantly lower difference in value in the framework-supported and incisal areas compared to the reference teeth. In general, the firing procedures led to a decrease in chroma in all ceramics. Hence, in many crowns a visible border between the framework area and the nonframework area was evident (Fig 7). Several studies have shown that the color of the framework material has an important effect on the color of a veneered crown.[16–18] In an in vitro examination, it was shown that leaving the platinum foil in jacket crowns led to a significant decrease in value compared to crowns without the foil.[16] Further, the gray framework of the metal-ceramic crowns also caused a decrease in value L.[16] Subsequent developments regarding veneering ceramics for metal frameworks have led to better masking abilities and improved esthetic outcomes.[17,18] Even after 5 to 6 firings, only slightly noticeable changes in value were observed with these new materials.[17,18]

Despite the superior masking ability of ceramic B, 2 layers of frame modifier were needed to completely cover the white zirconia framework. These 2 layers require additional removal of tooth substance. In an attempt to minimize the amount of tooth substance removed, tooth-colored zirconia framework material has been developed. Thus, less space for the framework, modifier, and veneering ceramic is presumably necessary. Nevertheless, to fulfill the highest esthetic demands, further improvements in the optical qualities of veneering ceramics are essential.

Another factor influencing the selection of a veneering ceramic is the technical manufacturing. During the manufacturing process, various difficulties are encountered. One such difficulty is high shrinkage during baking. This requires numerous corrective firings that lead to glazing and a subsequent loss of esthetic quality. Ceramics A and B were similar regarding the ease of manipulation. The relatively low shrinkage was judged as a positive factor by the dental technicians. Low shrinkage allowed easier and less time-consuming manufacturing of the crowns. Ceramic C, in contrast, exhibited high shrinkage and required several corrective firings.

Because of these shortcomings, restorations made with framework materials other than zirconia appear preferable for treatments in the esthetic zone. In situations where the esthetic demands are of lower importance, ceramic B will lead to acceptable results. However, to define the esthetic indications of zirconia reconstructions in the anterior region, more studies are necessary to compare the esthetic outcome of crowns using zirconia frameworks with those using glass-ceramic and metal frameworks.

Conclusions

The veneering ceramics for zirconia examined in this study failed to meet the highest esthetic demands. All 3 ceramics exhibited a high tendency for glazing. This glazing consistently allowed the white color of the zirconia framework to shimmer through the veneering ceramic, thus increasing the value of the crowns. Ceramic B led to the best color stability, whereas material C showed the least color stability.

To obtain veneering ceramics for zirconia frameworks that offer optimal esthetic results, improvements in the material properties and manufacturing process are clearly necessary. It can be expected that improved esthetic results will be achieved with increased clinical experience regarding the handling of these new ceramic materials.

Acknowledgments

The authors would like to gratefully acknowledge the 3 manufacturers of the veneering ceramics, GC Europe, Espident, and DeguDent, for supporting the study with the veneering materials. Further, they would like to thank Mr Martin Helmberger of Dekema and Labor Plus for the kind support with the 4 calibrated and preprogrammed furnaces. Finally, thanks to Mr Daniel Pally for his technical support with the production of study casts and frameworks, Dr Giorgio Menghini for his help with the statistical analysis of the data, and Yvonne Vidovic for her aid with the manuscript.

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Literature Abstract

Effect of in-office tooth bleaching on the microhardness of 6 dental esthetic restorative materials

This in vitro study evaluated the effect of an in-office bleaching technique on the microhardness of 6 dental esthetic restorative materials. The materials used for this study included 4 resin composites (1 hybrid resin [Tetric Ceram], 1 flowable resin [Tetric Flow], 1 microhybrid resin [Enamel Plus HFO], and 1 nanohybrid [Filtek Supreme]), an ormocer (organically modified ceramics) (Definite), and a porcelain (Vitablocs Mark II for Cerec). These represent the commonly used materials for esthetic restorations. The samples were prepared using 2-mm-thick transparent thermoforming discs, into which 4.5-mm-wide holes were drilled. The discs were positioned on a transparent plastic matrix strip on a glass plate. Upon inserting the materials into the discs, another transparent plastic matrix strip was placed on top to flatten the surface. The samples were light cured for 40 seconds using halogen light. The porcelain samples were prepared using Vitablocks Mark II using the Cerec 3D system. Seventy-seven samples were prepared in total—14 samples for each type of resin composite and ormocer and 7 samples for the porcelain. The samples were divided into polished and unpolished groups. For the porcelain, only polished samples were tested. Polishing of the samples was accomplished with Sof-Lex disks on a slow-speed hand-piece. All samples were stored in distilled water at room temperature for 24 hours prior to any procedure. The bleaching procedure used 38% hydrogen peroxide that was applied to the surface of the samples at 15, 30, and 45 minutes to simulate in-office bleaching conditions. Following each bleaching procedure, the samples were washed under running distilled water and placed in fresh distilled water until the next testing procedure. Five measurements were made for each sample using a Knoop microhardness tester. For the resin composite and ormocer samples, a 50 g load was applied for 30 seconds, whereas a 300 g load was used for the porcelain samples. Measurements were made first before bleaching, then after 15, 30, and 45 minutes of bleaching, and 24 hours and 1 month after the end of the bleaching procedure. The results were analyzed at a significance level of .05 using repeated measures analysis of variance. The results indicated that the differences in the microhardness values between the bleached samples and control samples were not statistically significant for all materials (Hybrid: $P = .264$; flow: $P = .584$; microhybrid: $P = .278$; nanohybrid: $P = .405$; ceramic: $P = .819$). Interestingly, the bleaching procedure on the ormocer caused an increase in microhardness of the polished samples. Based on the results of this study, the authors concluded that 38% hydrogen peroxide did not cause any significant reduction in the microhardness of the 6 dental esthetic restorative materials. Polishing of the resin composites did not have any effect on the microhardness. In addition, there is no indication to replace restorations following an in-office bleaching procedure.

Polydorou O, Monting JS, Hellwig E, Auschill TM. *Dent Mater* 2007;23:153–158. **References:** 31. **Reprints:** Olga Polydorou, Department of Operative Dentistry and Periodontology, Dental School and Hospital, Albert-Ludwigs-University, Freiburg, Germany. E-mail: olga.polydorou@uniklinik-freiburg.de—*Beatrice Leung, University of Toronto, Toronto, ON*