A New Approach to Compare the Esthetic Properties of Different Composite Materials

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ABSTRACT

Statement of the Problem: Modern composite systems are either very simple with few shades or very complex with an array of shades. Which approach gives the best esthetic results?

Purpose: The study aims to use a new approach to compare the esthetic properties of different composite materials and evaluate the ability of four different composite systems to imitate the natural shade of teeth.

Materials and Methods: Seventeen extracted teeth were restored using four different composite materials (Filtek Supreme XT [3M ESPE, Glostrup, Denmark], Ceram-X Duo [Dentsply-Friadent, Roskilde, Denmark], Tetric EvoCeram [Ivoclar Vivadent AB, Solna, Sweden], Enamel Plus HRI [Micerium, Avegno, Italy]). In total, 68 restorations were fabricated using the 17 teeth as their own control. This was made possible utilizing a device designed to remove exactly the same piece of tooth/composite every time. The time for placement and shades used were recorded. Two dentists evaluated the esthetic match of the restorations using slightly modified Extended Visual Rating Scale for Appearance Match criteria.

Results: There was a statistically significant difference ($p \leq 0.05$) between Filtek Supreme XT and Tetric EvoCeram and between Enamel Plus HRI and Tetric EvoCeram regarding the esthetic match. However, this was not deemed clinically relevant in most cases. Filtek Supreme XT required the most time, whereas Ceram-X Duo required the least time. There was a high intra- and interobserver agreement regarding ratings.

Conclusion: The study concluded that: (1) it was possible with all four composite systems to make restorations that were judged clinically acceptable in 91 to 96% of the cases; (2) more time was needed when using the more "advanced systems"; and (3) the new standardized, simple, and clinically relevant evaluation method was capable of comparing different composite systems' ability to imitate natural teeth.

CLINICAL SIGNIFICANCE

The four composite systems were able to make restorations that were deemed esthetically acceptable in 91 to 96% of the cases. Because Filtek Supreme XT and Enamel Plus HRI overall had more ratings of 0, they should be recommended for patients with the highest esthetic demands. Ceram-X Duo and Tetric EvoCeram should be recommended if time is a more important factor or the esthetic demands are less because of the reduction in time used while still obtaining esthetically good results.

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INTRODUCTION

Esthetic dentistry continues to grow exponentially as the incidence of caries declines and patients keep their teeth longer. Concomitantly, patients are demanding dental attractiveness as one of the principal outcomes of routine dental care. Today's dentist is able to meet the patient's requirements because the enamel/dentin adhesive systems currently available, and the substantial improvements in direct composite resins, have made restorations that are esthetically, biologically, and functionally adequate for anterior[1–3] as well as posterior teeth[4–6] possible. Even extensive defects in anterior teeth can now be repaired using composites in combination with tooth-colored posts and polyethylene ribbon.[7]

The ultimate goal of restorative dentistry is to restore missing tooth structure to its natural form, function, and appearance. This is a complex process that requires manipulation of the form, surface texture, translucency, and color of the restoration.[8] Consequently, dental esthetics lies at a crossroads between art and science. Art is not enough to create esthetic restorations, whereas science alone is inadequate to achieve pleasing results.[9]

Fortunately, composite layering techniques allow the clinician to accomplish restorations that are undetectable to the patient. Prerequisites are among other factors; the use of composite materials with different translucencies: "dentin," "enamel," and special effect materials (e.g., "yellow"). Nature is then mimicked by replacing dentin with an opaque composite and enamel using a more translucent composite.[10]

During recent years, there has been a tendency toward increasing the number of shades in the various composite systems. The large variety of commercial brands and shades among direct composite systems makes it difficult for experienced practitioners and, even more so, for undergraduate students to choose the best and most complete system.[11] Because of these difficulties, and the improvements offered by other products, indirect or semi-direct restorations using composite resin or porcelain are the front runners of esthetic dentistry.[12]

Most of the current resin composite systems contain translucent enamel and dentin shades. Some also provide opaque and bleach tooth shades as well. The resin composite restoration is then layered in a manner similar to making a porcelain crown.[13] However, using more shades is more time consuming and increases the number of possible combinations, thereby increasing the risk of choosing a potentially incorrect combination. The layering of composite with different shades and translucencies is especially difficult both because of the influence of thickness on the final shade and in choosing the right combination of colors.[14]

It has previously been proposed that the ideal composite material should have:[15,16]

1. dentin shades with a single hue, a single opacity, and a large chroma scale beyond the four chroma levels of the Vita System (Vita Zahnfabrik, Bad Säckingen, Germany)
2. three specific enamel types (young enamel, adult enamel, old enamel)

Typical brand names using this system are Ceram-X Duo (Dentsply-Friadent, Roskilde, Denmark) and Enamel Plus HRI (Micerium, Avegno, Italy). Other brands, like Filtek Supreme XT (3M ESPE, Glostrup, Denmark) and Tetric EvoCeram (Ivoclar Vivadent AB, Solna, Sweden), have chosen to follow the Vita System, thereby increasing the number of shades available (**Table 1**). Consequently, several layering concepts have been proposed according to the composition of the system. According to one classification,[17,18] the four composite systems mentioned previously can be divided into:

1. "Modern Two-Layer concept": Ceram-X Duo and Tetric EvoCeram use dentin and enamel shades in combination.
2. "Trendy three-layer concept": Filtek Supreme XT; essentially the two-layer concept with body shades added.
3. "Modern three-layer concept": Enamel Plus HRI; dentin and enamel shades with added effect shades.

TABLE 1. Comparison of The Four Composite Materials

	Dentin	Enamel	Other
Filtek supreme XT	A1D, A2D, A3D, A4D, A6D, B3D, C4D, C6D, WD, XWD	A1E, A2E, A3E, B1E, B2E, D2E, WE	A1B, A2B, A3B, A3.5B, A4B, B1B, B2B, B3B, C1B, C2B, C3B, D2B, WB, XWB, Y, G, V
Ceram-X Duo	DB, D1, D2, D3, D4	E1, E2, E3	
Tetric EvoCeram	A3.5D, A4D, B2D	A1, A2, A3, A3.5, A4, B2, B3, C1, C2, C3, D3	Bleach XL, Bleach L, Bleach M, Bleach I, T
Enamel Plus HRI	UD0, UD0.5, UD1, UD2, UD3,UD3.5, UD4, UD5, UD6	UE1, UE2, UE3	OG, IW, OA, OBN, IM, OW, IWS

For shortenings, see the individual manufacturer's homepage.

Therefore, if a simple system, like Ceram-X Duo, is capable of giving clinically acceptable results, both time and money can be saved. One has to remember that it will require a considerable amount of time to become accustomed to each brand, and, when changing brand, one will have to start all over again.[11] This is especially true if the practitioners preferred composite system is particularly advanced. A comparison of the esthetic properties of "simple" and more "advanced systems" is therefore appropriate.

MATERIALS AND METHODS

Using G*Power 1.0.10 (Franz Faul, University of Kiel, Germany), sample size was calculated to eight using $\alpha = 0.05$, $1-\beta = 0.80$, $SD = 1.5$, and a minimum difference on the modified Extended Visual Rating Scale for Appearance Match (EVRSAM) rating form of 2 (Table 2).

Seventeen teeth that had been stored in 0.2% chlorhexidine since extraction, and without any restorations, were scaled using both ultrasound and hand curettage. Afterwards, the teeth were polished with pumice and water and stored in distilled water at 4°C (39.2°F). The teeth were subsequently embedded in acrylic (Triad Gel, Dentsply, York, PA, USA) using the aluminum mold (Figure 1).
Putty impressions were made using President Putty Soft (Colténe/Whaledent AG, Altstätten, Switzerland) prior to sectioning in order to facilitate identical shapes of the composite buildups.

TABLE 2. Slightly Modified Extended Visual Rating Scale for Appearance Match (EVRSAM) Rating Scale

Modified EVRSAM	
Rating	Description
0	The restoration can only be delineated with difficulty
2	Very slight mismatch
4	Obvious mismatch but within an acceptable range for almost all patients
6	Poor esthetics on the borderline of acceptability
8	Very poor esthetics; unacceptable for nearly all patients
10	Totally unacceptable esthetics

Note: Intermediate ratings of 1, 3, 5, 7, and 9 may be given if the description of the esthetic match falls intermediate to any two adjacent descriptions given above.

A rectangular tooth piece was then cut out using a machine specifically designed for the purpose (Figure 1). The machine was designed to remove exactly the same piece of tooth/composite every time (Figure 2). Measurements made using a Mercer height measurer (Mercer Type 56, Mercer, St. Albans, UK), in between sectioning, showed only a 0.14-mm variation (0.24% variation) in the width of the remaining tooth.

After 24 hours of storage in distilled water,[19] pictures were taken using a standardized procedure with the teeth in the aluminum mold and using a fixed photo
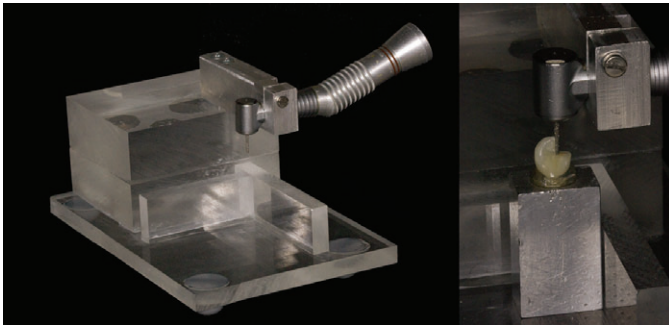
FIGURE 1. The specially designed machine used for sectioning the teeth.

FIGURE 2. A tooth before and after sectioning using the specially designed apparatus.

mount. A Canon EOS 300D with a Canon Macrolens EF100 mm 1:2.8 were used. (Canon, Amstelveen, the Netherlands). The camera set-up was made according to current recommendations.[20] The camera's white balance was calibrated using an 18% greycard and an F-stop of f22 was chosen. Lifting the teeth, only touching the acrylic base, meant excess water ran away from the crown, ensuring an equal degree of moisture on the teeth. The teeth were then again stored in distilled water for 24 hours.

The four manufacturers were allowed to decide and supply a bonding system of their choice. The four product systems used were: (1) Filtek Supreme XT and Adper Single Bond Plus Adhesive (3M ESPE), (2) Tetric EvoCeram and ExciTe (Ivoclar Vivadent AB), (3) Ceram-X Duo and XP Bond (Dentsply-Friadent), (4) Enamel Plus HRI and Enabond (Micerium, Avegno, Italy).

The restorations were done using Ergovision HD loupes with 2.5× magnification (Surgitel, Ann Arbor, MI, USA). MASTER TL-D 90 Graphica 58W/950 SLV light tubes (Philips, Amsterdam, the Netherlands), with specifications according to the current recommendations listed next, were used to illuminate the operating table.[21–26]

1. Correlated color temperature of 5,500 K
2. Color-rendering index of 98
3. Light with 1,500 lx (140fc)—checked using Hagner EC1 luxometer (B. Hagner AB, Solna, Sweden)
4. A neutral grey background with 18% reflectance (Kodak Gray cards, Kodak, New York, NY, USA)
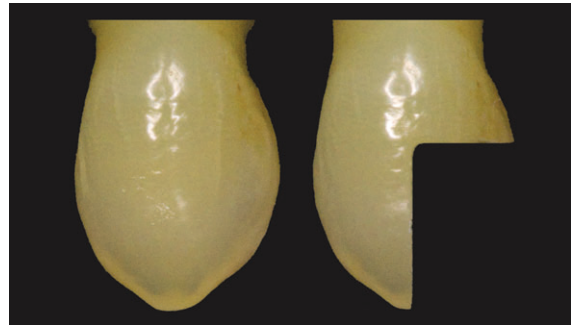
The 17 teeth were restored using the four different composite products and the putty template. All procedures were performed by the same operator (NØ) who had equal experience with all four composite systems. Shade selection was made according to the guidelines supplied by the manufacturers and using the shade guide supplied by the manufacturers. The manufacturers' recommendations regarding the different composite systems were used. This meant that Filtek Supreme XT restorations were made using a combination of dentin, enamel, body, and translucency colors, whereas Enamel Plus HRI restorations were made using a combination of dentin, enamel, and effect colors. The Ceram-X Duo and Tetric EvoCeram restorations were made using a combination of dentin and enamel colors. A mock-up to confirm the choice of shades was made before making the final restoration. Care was taken not to contaminate the facial surface with acid or the adhesive agent. No polishing was made to ensure that the surface of the tooth remained the same throughout the experiment. The shades used, time of day, and duration of procedures were recorded. After 24 hours of storage in distilled water, the teeth were then photographed again using the same standard mount.

The photos were taken as RAW image files and saved as tiff files. Two dentists rated the restorations using Uniscore (a photo rating program developed by Erik Gotfredsen, Department of Oral Radiology, School of Dentistry, Aarhus University, Denmark). Uniscore displayed the photos in a randomized order and stored the ratings given by the different operators. A Viewsonic Graphics Series G70fmb monitor

(Viewsonic, London, UK), calibrated using Spyder with Optial software 3.7.7 (Colorvision, Rochester, NY, USA), was used. The room had no windows or artificial lighting—the only light source came from the monitor. The EVRSAM criteria, slightly modified (Table 2), was used to evaluate the esthetic match of the restorations.[27]

STATISTICAL EVALUATION

Statistical analysis was performed with the aid of Statistix (Analytical Software, Tallahassee, FL, USA). A paired *t*-test was used to evaluate the difference between the different composite materials and between the time used. A significance of $p \leq 0.05$ was chosen.

Cohen's kappa was used to evaluate interobserver agreement. Pearson's correlation coefficient was used to evaluate intraobserver agreement.

RESULTS

There was only a statistical significance ($p \leq 0.05$) regarding the esthetic match between Filtek Supreme XT and Tetric EvoCeram and between Enamel Plus HRI and Tetric EvoCeram. Power analysis was carried out between the nonsignificant groups, which showed that 17 teeth with a $\beta = 0.80$ was sufficient. There was not a statistically significant difference between the esthetic ratings of the restorations made first compared with the restorations made last. There was only a significant decrease in time used to make the restorations.

The interobserver correlations were found to be $\kappa = 0.76$. The intraobserver correlations was found to be: observer 1: $\rho = 0.61$; observer 2: $\rho = 0.59$ (all with $p < 0.0001$).

Table 3 summarizes total time used for the four products. There was a statistically significant difference between all of the four systems. As **Figure 3** shows, there was a tendency that the average time used declined over time. As expected, the least advanced system, Ceram-X Duo, also demanded the least operator time.

DISCUSSION

Because all four composite systems were used to make exactly the same restoration on all 17 teeth, the teeth served as their own control (**Figure** 4). Embedding of the teeth in the aluminum mold, using acrylic, made it possible both to take photos of each tooth with various restorative materials and to remove the restorations without removing additional tooth substance than initially. In order to minimize operator error, only one operator made the restorations, and the sequence in which the restorations were made was randomized. Therefore, the design used in this study aimed at presenting a simple and clinically relevant method for evaluating new composite materials using remaining tooth structure as a control. The same design could be replicated by the practicing dentist using extracted teeth as a trial, for both training and evaluation, before using it in the patient's mouth.

Magne and So[28] describes a setup with certain similarities. The biggest difference is that Magne and So used a bevel, and consequently did not have a standardized approach. A bevel makes it difficult to identify the margin, which means you will not be able to place your restorations at the exact same finishing point every time, and you might end up making more of a composite veneer instead of a proximal restoration. Using a 90-degree cutoff instead, there are no problems identifying the margin. Furthermore, when making a bevel, both the width and angle play a role. Magne and So did not use a device to fabricate their bevel and

TABLE 3. Percentage Distribution of Ratings and Average Time Used

	Filtek supreme XT	Ceram-X Duo	Tetric EvoCeram	Enamel Plus HRI
Rating of 0 (%)	75.7	66.2	56.6	72.1
Rating of 2 (%)	18.4	25.7	34.6	24.3
Rating of 4 (%)	5.9	8.1	8.8	3.7
Minutes used	44.2	27.9	36.8	38.8

A rating of 4 was the worst used. Both a rating of 0 and of 2 is judged clinically acceptable for all patients.
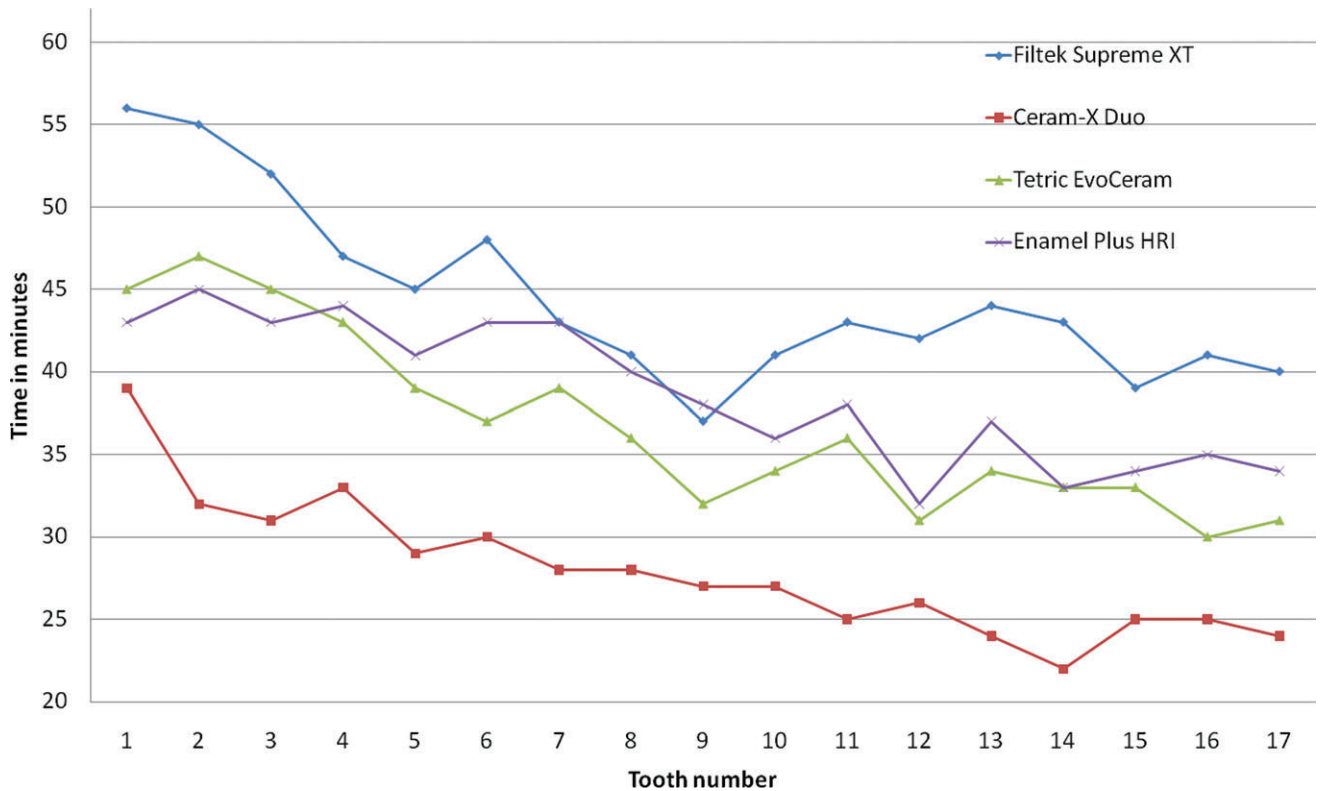
FIGURE 3. Time used to make the filling on each tooth for the individual products.

FIGURE 4. Example of the fillings made on the same tooth using the four different composite systems.

consequently they got a natural variation. Instead, the use of a cutting device (Figure 1) ensured that our restorations had the exact identical dimensions. Consequently, we only found an error of 0.24%.

Magne and So also used teeth stored in thymol. Several studies have shown that various storage mediums, often used in dental research, change the optical properties of the teeth.[29,30] Consequently, we used distilled water instead.

No polishing was made in order to avoid surface alterations. Studies have shown that both polishing in itself, and choice of polishing system, may change the ΔE2000 value significantly.[31] By not polishing we avoided potential bias. Magne and So used Sof-lex discs to remove excess composite and a glazing resin. However, Sof-lex discs may alter the surface, and it is not known in which way the resin affects the color, and if used intraorally it would quickly be worn off.

Using different light sources (direct, indirect, and fluorescent) were considered, as studies have shown that different light sources affect the perceived color of teeth.[32,33] However, this was not deemed clinically relevant because the use of direct, indirect, and fluorescent light is not practically possible in general

practice. However, a photo, or the use of optimal lightning conditions and an intraoral evaluation of what the restorations actually looks like, is possible.

The average time for making a restoration varied between 27.9 minutes for Ceram-X Duo and 44.2 minutes for Filtek Supreme XT. This must be because of the simple design of Ceram-X Duo which requires less time to master. However, there was a tendency that the time, especially for Filtek Supreme XT, decreased as the number of restorations made increased (Figure 3). Therefore, with further practice, the time difference should be minimized.

A minor error concerning the color of the restoration might not be noticed if the other criteria, such as surface texture, form, and opacity, have been appropriately replicated.[34] Therefore, an experiment comparing dentist and patient ratings could be performed. However, other studies have shown that dentists rate both patient smiles[35] and their work[36] harder than the patients do.

Despite the statistical significance between Filtek Supreme XT and Tetric EvoCeram and between Enamel Plus HRI and Tetric EvoCeram, this may not have clinical implications (Table 3). A rating of 4 would still be clinically acceptable for most patients, and from Table 3 it is clear that 4 was both the highest score given and being equally distributed between the four composite systems. Furthermore, none of the restorations received the rating of 4 by both evaluators at the same time. Magne and So[28] looked at the restorations in direct, indirect, and fluorescent lights but did not look at the time used. In accordance with the present study, they found that simple systems were able to make esthetically acceptable restorations. However, in their study, Filtek Supreme Plus (3M ESPE) showed the least favorable optical behavior, which in part was described by the lack of fluorescence and possible inappropriateness for use with the natural layering technique. Our study, though not looking at fluorescence, could not confirm this. However, the most significant factor is probably experience and time because our data showed that it was possible to make esthetically acceptable restorations. However, time used varied.

CONCLUSION

1. It was possible with all four composite systems to make restorations that were judged clinically acceptable for patients in 91 to 96% of the cases (a rating of 0 or 2)
2. More time was needed when using the more "advanced systems" compared with the "simple systems."
3. The good ratings achieved by all four composite systems, but the difference in time used, indicates that experience with a composite system is a major factor for achieving optimal esthetics.
4. By the evaluation method, it was possible to compare the abilities of the different composite systems to imitate natural teeth in a standardized, simple, and clinically relevant manner.

CLINICAL IMPLICATIONS

It was possible with all four composite systems to make esthetically acceptable restorations in 91 to 96% of the cases. Because Filtek Supreme XT and Enamel Plus HRI overall had more ratings of 0, they should be recommended for patients with the highest esthetic demands. Ceram-X Duo and Tetric EvoCeram should be recommended if time is a more important factor or the esthetic demands are less because of the reduction in time used while still obtaining esthetically good results.

DISCLOSURE AND ACKNOWLEDGEMENTS

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