Effects of whitening gels on color and surface properties of a microhybrid and nanohybrid composite

Tatjana SAVIC-STANKOVIC*, Branislav KARADZIC**, Vojislav KOMLENIC1, Jovana STASIC1, Violeta PETROVIC1, Jugoslav ILIC1 and Vesna MILETIC2

1Department of Restorative Odontology and Endodontics, School of Dental Medicine, University of Belgrade, Rankeova 4, Belgrade, Serbia
2Sydney Dental School, Faculty of Medicine and Health, The University of Sydney, 7/2 Chalmers Street, Surry Hills, NSW 2010, Australia

The aim of this study was to compare color changes, surface roughness and gloss of a microhybrid and nanohybrid composite whitened in a simulated in-office or at-home procedure using 40% hydrogen peroxide or 16% carbamide peroxide, respectively. CIELab coordinates were measured before, during and after treatment using VITA EasyShade V (VITA) and ∆E00 calculated. Surface roughness was measured using a surface roughness tester (SJ210; Mitutoyo). Gloss was measured using a gloss checker (IG-331; Horiba). At-home whitening resulted in ∆E00 of 1.23±0.49 (microhybrid) and 1.01±0.76 (nanohybrid). In-office exposure resulted in ∆E00 of 0.69±0.38 (microhybrid) and 0.72±0.50 (nanohybrid). There were no significant differences in ∆E00, surface roughness and gloss between whitening protocols (p>0.05). Color changes of a microhybrid and nanohybrid composite following simulated in-office or at-home whitening reached CIEDE2000 50:50% perceptibility but not acceptability threshold. Surface roughness and gloss of the microhybrid and nanohybrid composite were not affected by whitening.

Keywords: Composite, Whitening, Carbamide peroxide, Hydrogen peroxide, Color

INTRODUCTION

Tooth whitening is one of the most popular esthetic interventions with a significant effect on individual’s self-esteem and quality of life1-3. In-office or at-home whitening techniques are available involving different concentrations of hydrogen peroxide or carbamide peroxide, respectively. The whitening mechanism is based on the release of reactive oxygen molecules (O2•−) and hydrogen peroxide anions, hydroperoxyl (HO2•−) and hydroxyl (HO•). These ions act as strong oxidizing agents, capable of breaking longer-chained chromophores into shorter-chained colorless compounds4,5.

Whilst whitening agents have noticeable effects on vital and non-vital teeth4-7, their effects on resin-based composites remain unclear in terms of color differences and surface changes. Most studies have found color differences of non-discolored composites reaching or surpassing the CIEDE2000 50:50% perceptibility (∆E00=0.81) but below the 50:50% acceptability thresholds (∆E00=1.77)8-11, rarely color differences were shown to exceed the 50:50% acceptability threshold12,13. In general, the patients should be informed prior to the procedure that composite restorations will not present color differences comparable to teeth due to this limited effect of whitening agents on composite resin. Clinical relevance of this notion is that, in most cases, composite restorations will need replacement following whitening procedures. Both carbamide and hydrogen peroxide agents applied in at-home or in-office techniques, respectively, were reported to have a strong whitening ability on composites previously discolored in wine, tea or coffee14-16. Whitening effects were found to be material14,12,18, whitening agent8,14 or shade dependent8.

Inconclusive evidence exists regarding surface changes of resin-based composites. Increased roughness of microfilled and hybrid composites was associated only with 10–16% carbamide peroxide13. Both carbamide and hydrogen peroxide were reported to reduce gloss of hybrid and nanohybrid composites18. It was hypothesized that oxidizing agents may increase surface porosity of polymer matrix or filler debonding due to increased water uptake leading to changes in surface roughness and gloss18. A more recent review reiterated the inconclusive findings of the effects of whitening agents on surface topography with a similar number of studies reporting no effect or significant changes in surface topography8. Hydrogen peroxide (30–35%) was associated with changes in surface reflectance18. Increased surface roughness of hybrid and nanocomposites was found after treatment with whitening toothpastes, likely due to the abrasive effect of toothpastes and not whitening agents17.

Continuous research of the effects of whitening agents on optical and surface properties of composite materials is warranted in light of the differences in type, concentration and treatment protocols for various whitening agents as well as compositional changes in composite materials, a constantly evolving area. Composites with nanofiller particles are characterized by high filler load and discrete particles or agglomerated nanoclusters with filler particles below 100 nm, responsible for high polishability and gloss. In addition to

*These authors contributed equally to this work.
Color figures can be viewed in the online issue, which is available at J-STAGE.
Received Jan 28, 2021: Accepted May 13, 2021
doi:10.4012/dmj.2021-030  JOI JST.JSTAGE/dmj/2021-030
Table 1 Composite materials and whitening gels used in the study

| Material          | Manufacturer        | Type                     | Composition                                                                 |
|-------------------|---------------------|--------------------------|-----------------------------------------------------------------------------|
| Herculite XRV     | Kerr, Orange, CA, USA | Microhybrid composite    | Diurethane dimethacrylate (5–10 wt%); Bisphenol A ethoxylate dimethacrylate (5–10 wt%); 1,6-hexanediyl bismethacrylate (5–10 wt%); Triethylene glycol dimethacrylate (5–10 wt%); Hexamethylene diacrylate (1–5 wt%); 3-trimethoxysilylpropyl methacrylate (1–5 wt%); silica, barium alumino borosilicate glass, camphorquinone, ethyl dimethylamino benzoate |
| Herculite XRV Ultra| Kerr Italia, Scafati, Italy | Nanohybrid composite    | diurethane dimethacrylate (10–30%); trimethylolpropane triacrylate (10–30%); silica (10–30%), barium alumino borosilicate glass (30–60%), YbF3, prepolymerized filler, camphorquinone, ethyl dimethylamino benzoate |
| Power whitening WHITE Smile YF 40% | WHITEsmile, Birkenau, Germany | In-office, chemically activated tooth whitening gel (3×15–20 min) | 40% hydrogen peroxide (mixed 32 % hydrogen peroxide) Aqua, Hydrogen Peroxide, Silica, Glycerol, Organic amines, Polyglycols, yellow food color pH=8 |
| Whiteness Perfect | FGM Produtos Odontológicos, CEP, Brazil | At-home tooth whitening gel (3–4 h overnight) | 16% carbamide peroxide, potassium nitrate, sodium fluoride, pH=7 |

*According to manufacturer’s technical documentation
standardized volume of the whitening gel was applied directly from the syringe to the reservoirs in the whitening transparent tray and pressed against the composite specimens. The entire specimen surface was covered with gel without residual air-bubbles and stored in an incubator at 37°C for 4 h. The specimens were rinsed with distilled water to remove the whitening gel, blot-dried and stored in fresh distilled water in the incubator at 37°C. The treatment was repeated daily for 14 days. Color, surface gloss and roughness measurements were performed at baseline (T0), after 7 days (T7d) and after 14 days (T14d).

**Color, surface gloss and roughness measurements**

Color coordinates of each specimen were measured using a clinical spectrophotometer (VITA EasyShade V, VITA Zahnfabrik, Bad Säckingen, Germany). Prior to each measurement, the spectrophotometer was calibrated against the provided white background. Two readings were performed per specimen against the white reference tile relative to the standard illuminant D65. Color values were expressed in the CIEL*a*b* color system, where L* indicates lightness from white (L*=100) to black (L*=0), a* indicates red (+a*) or green (−a*) and b* indicates yellow (+b*) or blue (−b*) color components. Color differences (∆E00) before and after each whitening treatment were calculated using the following formula:

$$\Delta E_{00} = \sqrt{\left( \frac{\Delta L'}{K_{\text{L}00}} \right)^2 + \left( \frac{\Delta C'}{K_{\text{C}00}} \right)^2 + \left( \frac{\Delta H'}{K_{\text{H}00}} \right)^2 + R_T \left( \frac{\Delta C'}{K_{\text{C}00}} \right) \left( \frac{\Delta H'}{K_{\text{H}00}} \right)}$$

where ∆L’, ∆C’, and ∆H’ are metric differences computed on the basis of the uniform color space used in CIEDE2000. The empirical terms K_{\text{L}00}, K_{\text{C}00}, and K_{\text{H}00} are used for correcting (weighting) the metric differences to the CIEDE2000 differences for each coordinate. Parametric factors K_L, K_C, and K_H were set at 1. R_T accounts for the interaction between chroma and hue differences in the blue region.

Surface gloss was measured using a gloss-checker (IG-331; Horiba, Kyoto, Japan) at 60° with 3 readings per specimen. The specimens were placed in standardized custom-made molds which corresponded to detector dimensions to allow reproducible and stable specimen positioning. Prior to surface gloss measurements, the gloss meter was calibrated using manufacturer’s calibration blocks.

Surface roughness (R_s) was measured using a surface roughness tester (SJ210; Mitutoyo, Kanagawa, Japan) with 3 readings per specimen at a speed of 0.5 mm/min, N cut-off 5 and λc=0.8. The specimens were placed in standardized molds to allow reproducible and stable positioning.

**Statistical analysis**

Data were analyzed in Minitab 16 (Minitab, State College, PA, USA). Surface gloss and roughness baseline and final data were analyzed using a three-way ANOVA (general linear model) for factors “Composite”, “Treatment” and “Time” with 2 levels for each factor (XRV and XRV Ultra; In-office and at-home; Baseline and final, respectively) with factor interaction included. Two-way ANOVA was used to test the differences between factors “Composite” and “Treatment” using the final color difference data for in-office and at-home treatments. Two levels were included for “Composite” (XRV and XRV Ultra) and 2 levels for “Treatment” (in-office and at-home). Color differences at specific time intervals within in-office and at-home whitening were analyzed separately due to differences in treatment times, using a two-way ANOVA for factors “Composite” and “Treatment” with factor interaction included. Two levels were included for the factor “Composite” (XRV and XRV Ultra), 2 levels for at-home whitening (7 and 14 days) and 3 levels for in-office whitening (20, 40 and 60 min). Inter-group differences were tested using Tukey post-hoc test. The level of significance for all tests was 0.05.

**RESULTS**

Figures 1 and 2 present ∆E00 values (mean and standard deviation, SD) for the tested composites and whitening protocols. The final ∆E00 values for both XRV and XRV Ultra after in-office whitening reached CIEDE2000 50:50% perceptibility (∆E00=0.8) but remained below acceptability threshold (∆E00=1.8)11). Whilst the range of initial ∆E00 values for XRV after 7 days of at-home whitening reached the acceptability threshold, the final ∆E00 values for both composites after at-home whitening remained between the perceptibility and acceptability thresholds.

Regarding ∆E00, there was no significant interaction between factors for both in-office (p=0.151) and at-home (p=0.433) whitening protocols (Table 2). Between-group comparison within each factor showed no statistically significant differences between the tested composites for either whitening protocol (p=0.794 for in-office and p=0.561 for at-home protocol), as well as between different whitening intervals (p=0.722 for in-office and p=0.889 for at-home).

Two-way ANOVA comparing final ∆E00 between two whitening protocols showed no statistically significant difference between in-office and at-home (p=0.230) or between the two tested composites at the end of whitening procedures (p=0.783). Factor interaction was also not significant (p=0.613).

Table 3 shows mean and SD values of color coordinates L*, a* and b* at different whitening times. At-home whitening protocol with 16% carbamide peroxide resulted in increased L* and a* whilst b* decreased. In-office whitening protocol with 40% hydrogen peroxide resulted in unaltered L* and a* for XRV and slightly increased b*. In XRV Ultra, L* remained unaltered but a* and b* increased after treatment with 40% hydrogen peroxide.

Figures 3 and 4 present data for surface roughness and gloss, respectively. There was no significant interaction between factors for surface roughness or gloss (Tables 4 and 5). Further between-group
**Table 2** Summary of the statistical analysis for color differences ($\Delta E_{00}$) as a function of composite and time of in-office or at-home whitening

| Whitening protocol | Source          | Seq SS | Adj SS | $F$   | $p$   |
|--------------------|-----------------|--------|--------|-------|-------|
| In-office          | Composite       | 0.0119 | 0.0119 | 0.07  | 0.794 |
|                    | Time            | 0.1126 | 0.1126 | 0.33  | 0.722 |
|                    | Composite*Time  | 0.6981 | 0.6981 | 2.05  | 0.151 |
| At-home            | Composite       | 0.0833 | 0.0833 | 0.35  | 0.561 |
|                    | Time            | 0.0047 | 0.0047 | 0.02  | 0.889 |
|                    | Composite*Time  | 0.1532 | 0.1532 | 0.65  | 0.433 |

**Table 3** Mean (SD) values of color coordinates of XRV and XRV Ultra at different whitening times

| Composite  | Whitening | Time | $L^*$   | $a^*$  | $b^*$  |
|------------|-----------|------|---------|--------|--------|
| XRV        | T0        | 75.8 (1.7) | 1.5 (0.1) | 29.4 (1.1) |
|            | T7d       | 76.5 (1.1) | 1.6 (0.1) | 29.4 (0.5) |
|            | T14d      | 76.5 (0.6) | 1.7 (0.1) | 29.2 (0.6) |
| At-home    | T0        | 73.7 (0.9) | 2.2 (0.1) | 35.2 (1.0) |
|            | T7d       | 74.6 (0.6) | 2.3 (0.2) | 34.0 (0.9) |
|            | T14d      | 75.1 (1.1) | 2.2 (0.1) | 34.2 (0.6) |
| XRV Ultra  | T0        | 77.2 (1.4) | 1.5 (0.1) | 30.2 (0.7) |
|            | T20min    | 77.7 (1.4) | 1.4 (0.1) | 30.1 (0.8) |
|            | T40min    | 77.6 (0.8) | 1.4 (0.1) | 30.0 (0.9) |
|            | T60min    | 77.2 (1.0) | 1.5 (0.1) | 30.3 (0.6) |
| In-office  | T0        | 73.9 (0.9) | 2.0 (0.2) | 34.2 (1.3) |
|            | T20min    | 73.0 (0.9) | 2.2 (0.1) | 34.9 (0.5) |
|            | T40min    | 73.5 (1.3) | 2.1 (0.2) | 34.8 (0.8) |
|            | T60min    | 73.9 (0.8) | 2.1 (0.1) | 35.0 (0.5) |
Fig. 3 Surface roughness of XRV and XRV Ultra initially and after whitening. Groups sharing the same letter are not significantly different (p>0.05). Horizontal bars connect groups before and after treatment indicating no statistically significant difference (p>0.05).

Fig. 4 Surface gloss of XRV and XRV Ultra initially and after whitening. Groups sharing the same letter are not significantly different (p>0.05). Horizontal bars connect groups before and after treatment indicating no statistically significant difference (p>0.05).

| Source                | Seq SS  | Adj SS  | F      | p     |
|-----------------------|---------|---------|--------|-------|
| Composite             | 0.02391 | 0.02391 | 0.43   | 0.519 |
| Treatment             | 0.21190 | 0.21190 | 3.77   | 0.061 |
| Time                  | 0.01619 | 0.01619 | 0.29   | 0.595 |
| Composite*Treatment   | 0.07709 | 0.07709 | 1.37   | 0.250 |
| Composite*Time        | 0.00057 | 0.00057 | 0.01   | 0.921 |
| Treatment*Time        | 0.00196 | 0.00196 | 0.03   | 0.853 |
| Composite*Treatment*Time | 0.02948 | 0.02948 | 0.53   | 0.474 |

| Source                | Seq SS  | Adj SS  | F      | p     |
|-----------------------|---------|---------|--------|-------|
| Composite             | 476.1   | 476.1   | 6.82   | 0.014 |
| Treatment             | 0.9     | 0.9     | 0.01   | 0.910 |
| Time                  | 90.0    | 90.0    | 1.29   | 0.264 |
| Composite*Treatment   | 0.0     | 0.0     | 0.0    | 1.000 |
| Composite*Time        | 8.1     | 8.1     | 0.12   | 0.736 |
| Treatment*Time        | 16.9    | 16.9    | 0.24   | 0.626 |
| Composite*Treatment*Time | 10.0    | 10.0    | 0.14   | 0.707 |

Comparison within each factor showed no statistically significant differences in roughness between the tested composites (p=0.519), whitening protocols (p=0.061) and each composite before and after treatment (p=0.595). Between-group comparison for gloss showed significantly greater gloss for the nanohybrid XRV Ultra than the microhybrid XRV (p=0.014). There was no statistically significant difference in gloss between in-office and at-home whitening protocols (p=0.910) as well as for each composite before and after treatment (p=0.264).
DISCUSSION

Only the hypothesis that there is no difference in surface gloss between the tested microhybrid and nanohybrid composites was rejected as nanohybrid XRV Ultra was found to have significantly greater gloss than microhybrid XRV. Other hypotheses were upheld as no differences were found in color changes, surface roughness between the composites, whitening protocols and time intervals during whitening.

This study investigated the effects of 16% carbamide peroxide and 40% hydrogen peroxide, used for at-home or in-office whitening protocols respectively, on color and surface properties of a microhybrid and nanohybrid composite. Two composites from the same manufacturer were selected because of smaller compositional differences between such materials compared to those from different manufacturers. Even materials from the same manufacturer contain multiple variables, making it exceedingly difficult to interpret the differences in results. Further difficulty is created by the approach of many manufacturers to poorly disclose the composition of their materials in any meaningful way. The type and amount of resin matrix, size and distribution of filler particles, or photoinitiator system are often undisclosed by the manufacturers and these often critically affect material properties and differences between materials. A3 shade was selected because of its widespread use in clinical practice and high prevalence in natural teeth.

Treatment times were chosen as per manufacturer’s instructions. The length of at-home bleaching may be up to 4 weeks with 14 days being the most frequently used period. Only color differences immediately after whitening were measured to allow comparison of the effects of whitening agents. Possible changes in color perception in the post-treatment period are likely material-dependent and not related to whitening agents, e.g. water uptake and polymer hydrolysis affecting light penetration and reflectance.

The present results showed that color of both microhybrid and nanohybrid composite was affected by whitening treatment with 16% carbamide peroxide and 40% hydrogen peroxide. Color differences reached the 50:50% perceptibility but remained below the 50:50% acceptability threshold indicating that such differences are likely noticeable by the naked eye. The context of whitening, the acceptability threshold may be viewed as opposite to discoloration. Increased whitening of dental composites, similar to tooth whitening, would actually be desirable.

Numerous clinical studies have shown significant whitening effects of hydrogen- and carbamide peroxide on vital and non-vital teeth. Although whitening induces some color changes do occur in composites, the differences appear much smaller compared to color differences in teeth, only around the perceptibility threshold. This is probably the reason why it is often stated in the clinical practice that composite restorations do not whiten or bleach and why most composite restorations are replaced following tooth whitening.

Colored food and beverages contain organic pigments able to attach to or be absorbed within the resin polymer. Strong ability of whitening agents to lighten previously discolored composites has been reported. In such instances, the mechanism of whitening composites is similar to whitening teeth, i.e. the ability of oxidizing agents to break longer-chained chromophores in organic pigments into shorter-chained colorless compounds. Furthermore, oxidizing peroxide agents may interact with C-C single and C=C double bonds in resin polymers and residual photoinitiator molecules resulting in unspecific oxidation. This may be the mechanism of whitening previously non-discolored composites. Greater elution of monomers and additives and reduced elution of camphorquinone from bleached composites were reported by Durner et al.. Exposure of composite resin polymer to whitening agents leads to oxidative cleavage of the three-dimensional polymer network. Reduced amount of eluted camphorquinone from composite following exposure to peroxides is likely due to its break-down to unspecific oxidation products. Changes within the polymer initiated by oxidizing whitening agents result in different interaction with light and color perception of such composite.

The present result of no significant difference in color changes, surface gloss and roughness between different time intervals during whitening indicates a rapid oxidizing effect in composite which then reaches a plateau. Similarities in composition of the two tested composites in terms of resin matrix and independent of filler type, size and distribution may be the reason for comparable whitening effects and the lack of statistically significant differences.

Carbamide peroxide is known to convert to hydrogen peroxide during at-home whitening procedure, resulting in the same whitening mechanism as that of hydrogen peroxide during in-office whitening. Reduced concentration of the oxidizing agent is compensated by longer treatment time compared to a speedy in-office protocol. This is likely the reason for similar effects on composite color and surface properties (gloss and roughness) of the tested 16% carbamide peroxide and 40% hydrogen peroxide.

Interaction of oxidizing agents with resin polymer and changes within the polymer network, reflected in color differences, does not seem sufficient to produce a measurable effect on surface roughness and gloss of XRV and XRV Ultra. In general, slightly greater roughness was observed after whitening, but this did not reach the level of statistical significance. Other studies reported inconsistent results regarding the effect of whitening on surface roughness of composites. The effects were found to be material- and whitening agent-dependent, although a positive effect of saliva was also reported. Even if the effect of whitening agents on surface changes was measurable in vitro, it likely does not affect clinical appearance of composite restorations and may be mitigated by re-polishing.
CONCLUSIONS
Simulated in-office and at-home whitening with 40% hydrogen peroxide and 16% carbamide peroxide, respectively, of a microhybrid and nanohybrid composite resulted in color changes reaching or exceeding the 50:50% perceptibility but below the acceptability threshold. Both whitening protocols produced comparable effects regarding color changes of the tested composites. Whitening effects occurred during the first exposure interval and then reached a plateau without any significant effects for the remainder of treatment. Surface roughness and gloss of the microhybrid and nanohybrid composite were not affected by whitening.

ACKNOWLEDGMENTS
This study was supported in part by Research Grant ON172007 from the Ministry of Education, Science and Technological Development, Republic of Serbia. The authors would like to express their gratitude to Neodent RS for generous donation of materials used in this study.

CONFLICT OF INTEREST
No sponsorship or any other financial support was received from any of the companies mentioned in the study.

REFERENCES
1) Bersezio C, Estay J, Jorquera G, Peña M, Araya C, Angel P, et al. Effectiveness of dental bleaching with 37.5% and 6% hydrogen peroxide and its effect on quality of life. Oper Dent 2019; 44: 146-155.
2) Bersezio C, Ledezma P, Estay J, Mayer C, Rivera O, Fernández E. Color regression and maintenance effect of intracoral whitening on the quality of life: RCT-A one-year follow-up study. Oper Dent 2019; 44: 24-33.
3) Kwon SR, Wertz PW. Review of the mechanism of tooth whitening. J Esthet Restor Dent 2015; 27: 240-257.
4) Carey CM. Tooth whitening: what we now know. J Evid Based Dent Pract 2014; 14 Suppl: 70-76.
5) Savic-Stankovic T, Karadzie B, Latkovic M, Miletic V. Clinical efficiency of a sodium perborate – hydrogen peroxide mixture for intracoral non-vital teeth bleaching. Srp Arh Celok Lek 2020; 148: 24-30.
6) Klaric Sever E, Budimir Z, Cerovic M, Stambuk M, Par M, Negovetic Vranic D, et al. Clinical and patient reported outcomes of bleaching effectiveness. Acta Odontol Scand 2018; 76: 30-38.
7) Bersezio C, Ledezma P, Mayer C, Rivera O, Oliveira Jr OB, Fernández E. Effectiveness and effect of non-vital bleaching on the quality of life of patients up to 6 months post-treatment: a randomized clinical trial. Clin Oral Investig 2018; 22: 3013-3019.
8) Hafez R, Ahmed D, Youasy M, El-Badrawy W, El-Mowafy O. Effect of in-office bleaching on color and surface roughness of composite restoratives. Eur J Dent 2010; 4: 118-127.
9) Della Bona A, Pecho OE, Ghinea R, Cardona JC, Paravina RD, Perez MM. Influence of bleaching and aging procedures on color and whiteness of dental composites. Oper Dent 2019; 44: 648-658.
10) Pecho OE, Martos J, Pinto KVA, Pinto KVA, Baldisserra RA. Effect of hydrogen peroxide on color and whiteness of resin-based composites. J Esthet Restor Dent 2019; 31: 132-139.
11) Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, et al. Color difference thresholds in dentistry. J Esthet Restor Dent 2015; 27 Suppl 1: S1-9.
12) Ozturk C, Celik E, Ozden AN. Influence of bleaching agents on the color change and translucency of resin matrix ceramics. J Esthet Restor Dent 2020; 32: 530-535.
13) Attin T, Hannig C, Wiegand A, Attin R. Effect of bleaching on restorative materials and restorations — A systematic review. Dent Mater 2004; 20: 852-861.
14) Agnihotry A, Gill KS, Singhal D, Fedorowicz Z, Dash S, Pedrazzi V. A comparison of the bleaching effectiveness of chlorine dioxide and hydrogen peroxide on dental composite. Braz Dent J 2014; 25: 524-527.
15) Alharbi A, Ardu S, Bortolotto T, Kroeci I. In-office bleaching efficacy on stain removal from CAD/CAM and direct resin composite materials. J Esthet Restor Dent 2018; 30: 51-58.
16) Anagnoostou M, Chelioti G, Chiari S, Kakaboura A. Effect of tooth-bleaching methods on gloss and color of resin composites. J Dent 2010; 38: e129-136.
17) de Moraes Rego Roselino L, Tonani Torrielli R, Shardenello C, Amorim AA, Noronha Ferraz de Arruda C, Tirapelli C, et al. Color stability and surface roughness of composite resins submitted to brushing with bleaching toothpastes: An in situ study. J Esthet Restor Dent 2019; 31: 486-492.
18) Miletic V. In: Miletic V, editor. Dental Composite Materials for Direct Restorations. Spinger International Publishing AG; 2018. p. 3-9.
19) Ferracone JL. Resin composite — state of the art. Dent Mater 2011; 27: 29-38.
20) Manojlovic D, Dramicanin MD, Lezaja M, Pongprueksa P, Van Meerbeek B, Miletic V. Effect of resin and photoinitiator on color, translucency and color stability of conventional and low-shrinkage model composites. Dent Mater 2016; 32: 183-191.
21) Miletic V, Jakovljevic N, Manojlovic D, Marjanovic J, Rosic AA, Dramicanin MD. Refractive indices of unfilled resin mixtures and cured composites related to color and translucency of conventional and low-shrinkage composites. J Biomed Mater Res B Appl Biomater 2017; 105: 7-13.
22) Lezaja M, Veljovic DN, Jokic BM, Ccvijovic-Alagic I, Zrilic MM, Miletic V. Effect of hydroxyapatite spheres, whiskers, and nanoparticles on mechanical properties of a model BiogMA/TEGDMA composite initially and after storage. Biomed Mater Res Part B 2013; 101: 1469-1476.
23) Leprince J, Palin WM, Mullier T, Devaux J, Vreven J, Leloup G. Investigating filler morphology and mechanical properties of new low-shrinkage resin composite types. J Oral Rehabil 2010; 37: 364-376.
24) Salgado VE, Cavalcante LM, Silikas N, Schneider LF. The influence of nanoscale inorganic content over optical and surface properties of model composites. J Dent 2013; 41 Suppl 5: e45-53.
25) Elamin HO, Abubakr NH, Ibrahim YE. Identifying the tooth shade in group of patients using Vita Easyshade. Eur J Dent 2015; 9: 213-217.
26) Luque-Martinez I, Reis A, Schroeder M, Muñoz MA, Loguerccio AD, Masterson D, et al. Comparison of efficacy of tray-delivered carbamide and hydrogen peroxide for at-home bleaching: a systematic review and meta-analysis. Clin Oral Investig 2016; 20: 1419-1433.
27) Geisinger S, Kwon SR, Qian F. Employment of reservoirs in at-home whitening trays: Efficacy and efficiency in tooth whitening. J Contemp Dent Pract 2015; 16: 383-388.
28) Martins I, Onofre S, Franco N, Martins LM, Montenegro A, Arana-Gordillo LÁ, et al. Effectiveness of in-office hydrogen peroxide with two different protocols: A two-center
randomized clinical trial. Oper Dent 2018; 43: 353-361.
29) de Geus JL, de Lara MB, Hanzen TA, Fernández E, Loguercio AD, Kossatz S, et al. One-year follow-up of at-home bleaching in smokers before and after dental prophylaxis. J Dent 2015; 43: 1346-1351.
30) Reinhardt JW, Balbierz MM, Schultz CM, Simetich B, Beatty MW. Effect of tooth-whitening procedures on stained composite resins. Oper Dent 2019; 44: 65-75.
31) Joiner A. The bleaching of teeth: a review of the literature. J Dent 2006; 34: 412-419.
32) Durner J, Stojanovic M, Urcan E, Spahl W, Haertel U, Hickel R, et al. Effect of hydrogen peroxide on the three-dimensional polymer network in composites. Dent Mater 2011; 27: 573-580.
33) Rodrigues CS, Mozzaquatro LR, Dala Nora B, Jacques LB, Mullmann A. Effect of bleaching on color stability and roughness of composite resins aged in staining beverage. Gen Dent 2017; 65: e5-e10.