



ORIGINAL ARTICLE

Spectrophotometric study determining staining tendency in different restorative materials (longitudinal in vitro study)



Ghada Alhamed^a, Salsabil Massoud^a, Mazen Doumani^{b,*}

^a Department of Prosthetic Dental Science, College of Dentistry, Qassim University, Qassim, Saudi Arabia

^b Alfarabi Colleges of Dentistry and Nursing – Department of Restorative Dental Sciences, Riyadh, Saudi Arabia

Received 5 May 2020; revised 12 October 2020; accepted 1 November 2020

Available online 14 November 2020

KEYWORDS

Discolouration tendency;
Restorative materials;
Spectrophotometric;
Staining degree

Abstract *Aim:* Our aim was to measure the discolouration degrees in a packable composite, zircon, ceramic, a flowable composite, and GIC (glass ionomer cement) and to determine their tendencies to discolour to provide guidance to dentists and prosthodontist for choosing proper materials for cases in which aesthetics is the main treatment goal.

Materials and methods: Sixty discs were fabricated from the composite, zircon, ceramic, the flowable composite, and GIC, and natural teeth were the control group. The shades were recorded using the Ivoclar Vivadent Shade Guide, and readings were recorded from a Vita Easyshade 4.0 spectrophotometer before immersion, after 1 week, 2 weeks, 3 weeks, and 24 weeks of immersion in coffee. The analysis was performed using a SPSS paired *t*-test and CIE 76 formula.

Results: The ceramic had a starting shade of B1 and kept the same colour throughout the testing period. Zircon had a starting shade of A3 and transitioned to B3 by the second week. The composite had a shade of A1, and after the first week, it was A4; in the second week and afterwards, it was C4. The flowable composite had a starting shade of A1, and after one week, the shade was B3, and then after one more week A3.5; after five months, it was A4.

Conclusion: The ceramic showed no change, making it ideal for aesthetic regions and anterior replacements. Zircon had the second-highest colour stability, whereas all the other materials showed variable degrees of colour and surface changes, making them not ideal choices for anterior

* Corresponding author.

E-mail addresses: Ghada.AlHamed@QuDent.org (G. Alhamed), dr.salsabil.massoud@qudent.org (S. Massoud), mazendom@hotmail.com (M. Doumani).

Peer review under responsibility of King Saud University.



Production and hosting by Elsevier

restorations. Thus, this information can aid choices for aesthetic regions to provide the highest longevity.

© 2020 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

At this advanced time, aesthetics can be the main reason patients visit a dentist. A patient visiting a prosthodontist visits with the wish for the best aesthetic result possible. This results in aesthetic results being equally as important to physical and mechanical proprieties (Mitra et al., 2003; Pallesen and Qvist, 2003). Restorative materials that match the tooth colour should have excellent colour matching and high colour stability throughout their clinical service (Conrad et al., 2007; Schneider et al., 2008). Restorative materials are threatened by the many and frequent changes of oral conditions, thus causing discolouration of the chosen restorative material. Prior studies have stated that of all the tooth-coloured restorative materials, composite resin has a good likelihood of discolouring intraorally (Della Bona and Kelly, 2008; Karaarslan et al., 2014). Because composite resins are susceptible to staining, immersing in coffee or tea is a reliable test method for mimicking oral conditions, providing a good understanding of the susceptibility of the material to discolour. (Demarco et al., 2015) Glass ceramic has been chosen as the ideal aesthetic restoration material owing to its translucency, which resembles the natural tooth effect (Carney et al., 2017; Bankoğlu Güngör et al., 2018; Shahmiri et al., 2018). Zirconia-based ceramics have been developed to supply the demand for a stronger glass ceramic restoration material that has aesthetic and functional abilities (Lee et al., 2016; Tuncel et al., 2016). Currently, monolithic zirconia restorations fabricated via CAD-CAM technology have superior mechanical properties and are made via an easy preparation technique (Acar et al., 2016; Shiraishi and Watanabe, 2016). According to studies, composite resin has excellent aesthetic properties, making it an ideal choice for anterior teeth restorations (Demarco et al., 2015; Can Say et al., 2014). However, patients often return complaining of discolouration of the composite resin (Yildiz et al., 2015). The novelty of this study was that we examined the most commonly used restorative materials under the same conditions to determine the superiority regarding colour stability and which mimics natural teeth in terms of discolouration tendency. LCH is a numerical representation of colour.

1.1. Aim

We aimed to determine the tendency of materials to discolour and measured the discolouration degree of each material compared to natural teeth.

1.2. Hypothesis

We hypothesised that ceramic and zircon will show minimal colour changes, whereas GIC, the flowable composite, and composite would show higher discolouration tendencies.

2. Materials and methods

Ethical clearance No. F-2018–3014 was granted by the committee of ethical review at the Qassim university institution. The study was performed in the Female Dental Clinic of Qassim University. The study was a longitudinal in vitro study and financed by the researcher and the Qassim University Dental College. Ten discs of five types of restorative material (ceramic, zirconia, composite, flowable composite and GIC) (Table 1) were fabricated by a Qassim University dental laboratory technician using multiple (vinyl polysiloxane impression material putty) standard-sized templates (Fig. 1). Standardisation was insured by fabrication of one disc and stamping the impression with the same disc ten times for each packable material (composite, flowable composite, and GIC). For zircon, an inlay was milled inside an acrylic tooth with the same dimensions as the packable template and then scanned into a CAD/CAM device (inLab MC X5), repeating ten times. The ceramic was waxed and then manually pressed. Ten (7*2 mm) discs were fabricated from each material.

After curing the samples, they were retrieved from the molds. Ten natural teeth were obtained with inclusion criteria of: sound teeth, no caries, and no discolouration. Any teeth

Table 1 Material composition.

Ceramic	inCoris TZI C disc
Zircon	IPS e.max ZirCadMTMULTI
Composite	Filtek™ Z250 Universal Restorative
Flowable	Filtek™ Supreme Ultra Flowable
Composite	Restorative
GIC	ChemFil Rock Dentsply Sirona

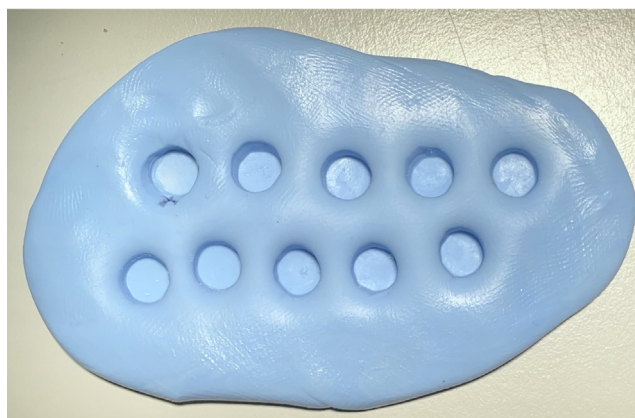


Fig. 1 Template made with Vinyl Polysiloxane impression material putty.

that were broken or obtained from medically compromised patients that caused discolouration and who used medication (s) causing discolouration were excluded. To replicate patient oral conditions more accurately, specimens were kept in a humid environment at a temperature of 37 °C during the entire testing period and subjected to staining solutions. Each material was kept in its individual coffee container (Dunkin Donuts Original Blend Medium Roast Ground Coffee) and measured periodically after being immersed in water for 5 s to closely mimic salivary flow. Since visual colour change can be used as a judging quality control method and guideline for selecting the proper aesthetic materials (Paravina et al., 2015), Ivoclar Vivodent Shade Guide was used to record the result. To insure accurate results, VITA Easyshade® Advance 4.0 (a spectrophotometer) was utilized to record the results at each stage of the experiment. Stage 1 involved recording the starting shade of each test group in which the natural teeth labial/buccal surface was examined. Stage 2 involved measuring after 1 week of immersion in coffee. Stage 3 was after 2 weeks. Stage 3 was after 3 weeks. Stage 4 after 24 weeks. The Vita Easyshade® spectrophotometer was used to obtain numerical readings of any slight colour change. The values of Luminance-Chroma-Hue (LCH) were then converted to LAB using this formula:

$$a^* = C * \cos(h^\circ), \quad b^* = C * \sin(h^\circ)$$

The International Commission on Illumination 1976 (CIE76) formula was used to compare the control in each group to the rest of the group. The CIE76 colour difference formula states that if the colour change value is $\Delta E = 2.3$, then it is considered a JND (just noticeable difference). The following formula was used to convert a^* and b^* to C^* and h° :

$$C^* = \sqrt{(a^*^2 + b^*^2)}, \quad h = \text{atan2}(b^*, a^*)$$

3. Results

Shade readings were recorded via the Ivoclar shade guide (Table 2). The ceramic remained the same colour, whereas zirconia changed from A1 to B3. All other materials changed significantly. The results were confirmed via Vita EasyShade Advance 4.0, confirming the shade guide result with minor differences. Numerical readings of the LCH were also recorded using the Vita EasyShade Advance 4.0 and were converted to LAB as previously mentioned; then, each reading was compared to the control in each group (Table 3). The ceramic showed the lowest change at 0.4 with minimal change in the twenty-fourth week. However, the composite showed a change of up to 18.29 in the third week. A paired T-test was performed

to compare each sample to a natural tooth, and no significance was recorded with a P value above 0.05. The closest was 0.065 for the composite (Table 4).

4. Discussion

Excellent colour matching to the natural tooth is the main concern when choosing a visible restoration; however, no papers have been published that compared all restorative materials with controlled conditions to provide an ideal restorative choice. The stability of the colour is one of most important characteristics of composite resin in terms of longevity (Mundim et al., 2010). The top layer of the composite resin is in direct contact with oxygen and does not undergo complete polymerization. Thus, this layer becomes more porous, and water sorption is more likely to occur, making surface discolouration possible. (Gauthier et al., 2005). The surface composite resin degradation and consequent pigmentation process could be affected by chemical components present in beverages that are consumed daily (Gauthier et al., 2005). Coffee has in its composition a yellow dye that interacts with the composite resin organic layer and is responsible for its staining capability (Bagheri et al., 2005). The glass ceramic showed the best result in our study, which makes it an ideal aesthetic restoration as confirmed by multiple other studies (Carney et al., 2017; Bankoğlu Güngör et al., 2018; Shahmiri et al., 2018). Despite the lack of translucency of zircon, it overcame the results of packable materials in terms of staining tendency. R. AlSheikh tested a Lucirin-photo-activated resin composite staining using a spectrophotometer, which was similar to our study (AlSheikh, 2019). Pigmented liquids stain resins via adsorption or absorption (Amin et al., 2012). Tannic acid causes discolouration in coffee (AlSheikh, 2019). Subramanya et al. stated that the colour could be rapidly analysed by computerized image analysis techniques, also known as computer vision systems (Amin et al., 2012). In our opinion, the result could be influenced by the taken photo, lighting, or even the perception by the computer of the image. Using a spectrophotometer in a controlled environment reduces the chance of errors when recording the colour. The CIELAB colour system is the assessment of choice owing its ability to quantify the result (Türkün et al., 2010). The ΔE shows the colour change before and after the change is introduced. According to the literature, values of $\Delta E < 1$ cannot be detected, whereas values of $1 < \Delta E < 2.3$ are detectable by skilled personnel but accepted clinically, whereas values of $\Delta E > 2.3$ are detectable by non-skilled persons, preventing them from being accepted clinically (Subramanya and Muttagi, 2011). As a result, $\Delta E = 2.3$ would not be accepted clinically. Thus, if a certain difference in terms

Table 2 Ivoclar Vivodent Shade Guide Readings.

	Ceramic	Zircon	Composite	Flowable composite	Gic	Natural tooth
Control	B1	A1	A1	A1	A2	A1
Week 1	B1	A3	A4	B3	B3	A4
Week 2	B1	B3	C4	A3.5	C4	A1
Week 3	B1	A3	C4	A3.5	A1	C1
Week 24	B1	B3	C4	A4	B3	A4

Table 3 Numerical Colour Change.

	Ceramic	Zircon	Composite	Flowable composite	Gic	Natural tooth
Week 1	1.36	2.50	15.87	9.68	3.86	10.38
Week 2	4.47	2.21	9.77	4.55	5.50	5.70
Week 3	3.40	0.84	18.29	4.67	3.47	4.12
Week 24	0.40	5.94	7.32	7.93	5.01	3.28

Table 4 Paired Sample T-Test comparing each material to a natural tooth.

	Paired differences	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		T	DF	Sig. (2-Tailed)
					Lower	Upper			
Pair 1	<i>Ceramic - NaturalTooth</i>	-3.46250	3.81796	1.90898	-9.53773	2.61273	-1.814	3	0.167
Pair 2	<i>Zircon - NaturalTooth</i>	-2.99750	4.32699	2.16349	-9.88270	3.88770	-1.385	3	0.260
Pair 3	<i>Composite - NaturalTooth</i>	6.94250	4.86560	2.43280	-0.79976	14.68476	2.854	3	0.065
Pair 4	<i>F.composite - NaturalTooth</i>	0.83750	2.64146	1.32073	-3.36565	5.04065	0.634	3	0.571
Pair 5	<i>GIC - NaturalTooth</i>	-1.41000	3.55965	1.77983	-7.07420	4.25420	-0.792	3	0.486

**Fig. 2** All tested samples placed on a black backdrop while being measured.

of ΔE_{00} is observed, there will be a difference in how this change is perceived by the untrained eye and, if it is, whether this change is clinically significant. The subjectivity of the value makes it difficult to establish clinical significance. A surface texture change was noted for the composite, flowable composite, and GIC, increasing the likelihood to retain the colour with surface roughness (Fig. 2). The change was caused by the acidification from immersion in coffee. GIC showed a fluctuating discolouration degree, which can be caused by the change in porousness and significantly decreased opacity. The Ivoclar Vivadent Shade Guide depends mainly on the researchers

observational skill and his/her ability to detect the slightest colour change. Therefore, this method is less reliable than the use of Vita Easyshade 4.0 spectrophotometer, which produces consistent results.

5. Conclusion

Ceramic showed no change, making it ideal for aesthetic regions and anterior replacements. Zircon showed the second highest value for colour stability, whereas all the other materials showed variable degrees of surface and colour changes,

making them not ideal choices as anterior restorations. Thus, these results can aid choices in aesthetic regions to provide the highest longevity.

5.1. Recommendations

Using different immersion solutions, different restorative materials can be tested, such as CAD/CAM IPS Impress. The immersion period can be elongated.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors have no financial obligations towards any companies whose materials were included in this study.

References

- Mitra, S.B., Wu, D., Holmes, B.N., 2003. An application of nanotechnology in advanced dental materials. *J. Am. Dent. Assoc.* 134, 1382–1390.
- Pallesen, U., Qvist, V., 2003. Composite resin fillings and inlays. An 11-year evaluation. *Clin. Oral Investig.* 7, 71–79.
- Conrad, H.J., Seong, W.J., Pesun, I.J., 2007. Current ceramic materials and systems with clinical recommendations: a systematic review. *J. Prosthet. Dent.* 98, 389–404.
- Schneider, L.F., Pfeifer, C.S., Consani, S., Prah, S.A., Ferracane, J.L., 2008. Influence of photoinitiator type on the rate of polymerization, degree of conversion, hardness, and yellowing of dental resin composites. *Dent. Mater.* 24, 1169–1177.
- Della Bona, A., Kelly, J.R., 2008. The clinical success of all-ceramic restorations. *J. American Dental Assoc.* 139, 8S–13S.
- Karaarslan, E.S., Ertas, E., Bulucu, B., 2014. Clinical evaluation of direct composite restorations and inlays: results at 12 months. *J. Restor. Dent.* 2, 70–77.
- Demarco, F.F., Collares, K., Coelho-De-Souza, F.H., Correa, M.B., Cenci, M.S., Moraes, R.R., Opdam, N.J., 2015. Anterior composite restorations: a systematic review on long-term survival and reasons for failure. *Dent. Mater.*
- Bankoğlu Güngör, Merve; Karakoca Nemli, Secil, 2018. Fracture resistance of CAD-CAM monolithic ceramic and veneered zirconia molar crowns after aging in a mastication simulator. *National Library of Medicine. The Journal of prosthetic dentistry.* Vol. 119, Iss., 3, 473-480.
- Shahmiri, Reza; Standard, Owen Christopher; Hart, Judy N; Sorrell, Charles Christopher, 2018. Optical properties of zirconia ceramics for esthetic dental restorations: A systematic review. *National Library of Medicine. The Journal of prosthetic dentistry* Vol. 119, Iss. 1, 36-46.
- Carney, Melody N; Johnston, William M, 2017. Appearance Differences Between Lots and Brands of Similar Shade Designations of Dental Composite Resins *Journal of Esthetic and Restorative Dentistry; Oxford* Vol. 29, Iss. 2, E6-E14.
- Lee, Wei-Fang; Feng, Sheng-Wei; Lu, Yi-Jie; Wu, Hsin-Jui; Peng, Pei-Wen; et al, 2016. Effects of two surface finishes on the color of cemented and colored anatomic-contour zirconia crowns. *The Journal of prosthetic dentistry* Vol. 116, Iss. 2, 264-268.
- Tuncel, İlkin; Turp, Işıl; Üşümez, Ashhan, 2016. Evaluation of translucency of monolithic zirconia and framework zirconia materials. *National Library of Medicine. The journal of advanced prosthodontics* Vol. 8, Iss. 3, 181-186.
- Shiraishi, Takanobu, Watanabe, Ikuya, 2016. Thickness dependence of light transmittance, translucency and opalescence of a ceria-stabilized zirconia/alumina nanocomposite for dental applications. *Dental Mater.* 32 (5), 660–667.
- Acar, Ozlem; Yilmaz, Burak; Altintas, Subutay Han; Chandrasekaran, Indumathi; Johnston, William M; et al, 2016. Color stainability of CAD/CAM and nanocomposite resin materials. *The Journal of prosthetic dentistry* Vol. 115, Iss. 1, 71-75.
- Can Say E, Yurdagüven H, Yaman BC, 2014. Ozer F. Surface roughness and morphology of resin composites polished with two-step polishing systems. *Dent Mater.*
- Yildiz, E., Sirin Karaarslan, E., Simsek, M., Ozsevik, A.S., Usumez, A., 2015. Color stability and surface roughness of polished anterior restorative materials. *Dent. Mater.*
- Paravina, R.D., Ghinea, R., Herrera, L.J., Bona, A.D., Igiel, C., Linninger, M., Sakai, M., Takahashi, H., Tashkandi, E., Perez Mdel, M., 2015. Color difference thresholds in dentistry. *J Esthet Restor Dent.* 27, S1–S9.
- Mundim, F.M., Pires-de-Souza, F.D.C.P., Garcia, L.D.F.R., Consani, S., 2010. Color stability, opacity and cross-link density of composites submitted to accelerated artificial aging. *European J. Prosthodontics Restorative Dentist.* 18 (2), 89–93.
- Gauthier, M.A., Stangel, I., Ellis, T.H., Zhu, X.X., 2005. Oxygen inhibition in dental resins. *J. Dent. Res.*
- Bagheri, R., Burrow, M.F., Tyas, M., 2005. Influence of food-simulating solutions and surface finish on susceptibility to staining of esthetic restorative materials. *J. Dent.*
- AlSheikh, R., 2019. Color stability of Lucirin-photo-activated resin composite after immersion in different staining solutions: a spectrophotometric study. *Dove Press*, p. 11.
- Amin, Faiza; Moosa, Shumaila Iqbal; Abbas, Muhammad. 2012. Effect of Staining Solutions on the Color Stability of Direct Resin Composite. *Pakistan Journal of Medical Research*; 51(4): 123-126.
- Türkün, M., Celik, E.U., Aladağ, A., Gökay, N., 2010. One-year clinical evaluation of the efficacy of a new daytime at-home bleaching technique. *J. Esthet. Restor. Dent.* 22 (2), 139–146.
- Subramanya, J.K., Muttagi, S., 2011. In vitro color change of three dental veneering resins in tea, coffee, and tamarind extracts. *J. Dent.* 8 (3), 138–145.