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Original Article

Dentistry Section

The Effect of Accelerated Aging on the Colour Stability of Composite Resin Luting Cements using Different Bonding Techniques

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ABSTRACT

Introduction: The main criterion of successful aesthetic restoration is to match the colour of the adjacent teeth. Porcelain laminate veneer is widely practiced indirect restoration in the contemporary aesthetic dentistry. The underlying luting cement colour influences the final outcome of the thin, translucent veneer shade. Hence, colour stability of luting cement is important criteria during their selection.

Aim: The objective of the study was to assess the colour stability of the different dentin bonding techniques in composite resin luting cements.

Materials and Methods: A total of forty intact, non carious teeth were prepared to receive Porcelain Laminate Veneers (PLV). The lithium disilicate PLV were fabricated, and fitting surface was conditioned with 5% hydrofluoric acid and silane application. According to the bonding technique employed for the cementation of the PLV, the teeth samples were randomly divided into the four groups of ten each. The Group I and Group II samples were conditioned with etch and wash; the polymerization of resin was accomplished with the dual cure for Group I and light cure for Group II. The Group III and Group IV samples were conditioned with self-etch and self-adhesive technique correspondingly. The teeth shade was recorded in similar locations with a spectrophotometer before and after subjecting them to the accelerated ageing process. The ageing process included the thermocycling process in water between 5°C and 55°C for 5000 cycles followed by 100 hours xenon light exposure. The data were analysed with SPSS 19.0 by ANOVA and LSD post-hoc comparison.

Results: The higher mean colour change was observed in Group I sample (etch washdual cure) with a ΔE value of 2.491. The ΔE value for Group II (etch wash-light cure) and Group III (selfetch) was 1.110 and 2.357 respectively. The lowest mean colour change was observed in Group IV (self-adhesive) with ΔE at 0.614. Statistical analysis showed significant differences between Group IV and Group I; Group IV and Group III with $p<0.05$.

Conclusion: The self-adhesive and etch-wash light cure luting cements were found to be less susceptible for colour changes due to accelerated ageing.

Keywords: Ceramic laminate veneers, Composite resin cements, Tooth shade

INTRODUCTION

Ceramic veneers are the predictable aesthetic restorations with estimated average life more than ten years [1]. The silica based glass ceramics are commonly used for the fabrication of laminate veneers due to their excellent aesthetic properties. The inclusion of lithium-disilicate and leucite has led to significant improvement in the fracture resistance of glass ceramics [2]. Fabrication of the all ceramic restoration with the colour resembling the natural dentition is a challenge in dentistry. The translucency of PLV adds another level of complexity to the colour matching [3]. The underlying substrates have a significant influence on the final colour outcome. The composite resin cements are regularly used for cementation of PLV restoration due to their strong, durable bond and ceramic reinforcing effect [4]. However, some composite resins are reported to go through external and internal discolouration [5]. Both colour matching and the colour stability are imperative for the long term success of the aesthetic restorations [6]. Any discolouration of adhesive resin cement may show through and affect the appearance of all-ceramic restorations. The structural changes and formation of degradation products are mainly attributed to the intrinsic colour changes in the composite resin cements [7,8]. The structural changes observed in chemically activated cements are due to the oxidation of reactive groups in amine accelerators and inhibitors [5,9]. Hence, the knowledge of these colour changes is important to the dentist while choosing the suitable cement.

The etch-wash, self-etch and self-adhesive techniques are employed during the luting procedure involving resin cements. The adhesive strength, dentin interaction, and bonding mechanisms are significantly different between these bonding techniques. Researchers have shown that the hydrophilicity of bonding systems lead to the structural and colour changes in the composite resins [10,11]. Previous studies have also evaluated the colour stability of resin cement due to ageing process and mode of polymerization [12-14]. The influence of various bonding techniques employed during composite resin cementation on the long term colour stability requires the further evaluation and understanding. Hence, this in vitro study was designed to evaluate the effect of different enamel-dentin bonding techniques on the colour stability of composite resin cement after accelerated ageing.

MATERIALS AND METHODS

The study protocol was approved (number SRC/REG/2015-2016/63) by the Institutional Ethical Committee, College of Dentistry, King Khalid University; it was conducted during the first academic semester of 2016. Forty non carious, sound human maxillary premolar teeth extracted for orthodontic reasons were used in this in vitro study. The exclusion criteria for teeth samples included caries, large restorations, abrasion, microcracks, discolouration and white spot lesions. After removal of dental plaque, calculus, and periodontal fibres, the teeth were stored in distilled water at room temperature until the preparation for the study. The teeth samples were randomly divided into four groups (n=10) of ten each according to the adhesive system used for luting the PLV. All teeth samples were mounted in acrylic resin blocks to provide better control during tooth preparation. The facial surface reduction was initiated by preparing 0.6 mm horizontal grooves with the help of depth preparation diamond bur (Diatech, Coltane. AG, Switzerland). The facial surface was painted with waterproof paint to enable the uniform reduction. The painting of the surface was helpful in differentiating the contrast between prepared and unprepared teeth. The anatomical reduction of the facial surface was accomplished by using the round ended diamond bur in three different planes until the colour at the bottom of grooves disappears. The chamfer finish line at the gingival margin was prepared. The proximal area preparation was completed with a round ended tapered bur along the long axis of the tooth. Cusp overlap was accomplished with 1.5 mm cusp reduction and extending the reduction onto the lingual incline of the buccal cusp by 2 mm. Single operator prepared all the teeth used in the study.

Fabrication of the Porcelain Veneers

A total of forty PLV were fabricated from lithium disilicate glass ceramic ingots (IPS Empress Esthetic, Ivoclar, Schaan/Liechtenstein) with ETC1 shade. The PLV samples were made by burnout and heat pressing of 0.7 mm thickness wax pattern at 920^0C. The neutral glaze was applied over the outer surface of the PLV by firing ceramic samples at 765^0C. Since smooth and polished porcelain is considered necessary for porcelain's colour stability, surface polishing was performed using 3 mm and 6 mm diamond polishing burs and paste.

All PLV fitting surfaces were etched with 5% hydrofluoric acid (IPS ceramic etching gel) for 20 seconds, subsequently washed thoroughly with water and dried with oil free air. The samples were ultrasonically cleaned for 10 minutes, following this, a monocomponent silane (Monobond Plus) was applied to the conditioned surface. It was allowed to react for one minute and thoroughly scattered with air. The corresponding tooth surfaces were conditioned with four different adhesive system following the manufacturer's instructions [Table/Fig-1].

Colour Stability Evaluation

The colour determination of each sample was accomplished by the colour spectrometer (easy shade-VITA Zahnfabrik, Bad Säckingen, Germany). The ceramic veneer was divided into three equal parts with the help of a digital caliper as cervical, middle and incisal portions. The central part of each segment was selected for measuring the colour and used as reposition demarcation for future reference. The CIELAB detail of each location was tabulated; the average of all three areas was regarded as the reference colour of the PLV specimen.

Following the colour determination of each sample, PLV samples were subjected to accelerated aging by thermocycling process in water between 5°C and 55°C for 5000 cycles with a dwell time of 30 seconds. The samples were further exposed to the xenon lamp of 7000^0K and 150000 Lux. The light exposure duration was for 100 hours and during the light exposure the temperature was maintained at 37^0C with 100% humidity.

Following the accelerated ageing process, follow up colour measurements were performed following a similar procedure at the identical areas for each sample.

The colour differences (ΔE) were determined using the coordinates L*, a* and b* by using formula [12]:

$$\Delta E^* = \{(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2\}1/2$$

Where ΔL* is the variation of L*, Δa* is the variation of a*, and Δb* is the variation of b*. The statistical analysis was performed with SPSS 19.0 software (IBM Corporation, Armonk, New York, USA). The values obtained for L*, a*, b* and ΔE* were subjected to ANOVA and LSD post-hoc comparison at the significance level p=0.05.

RESULTS

The luting cements used in the study had various ranges of colour change after the accelerated ageing process. The mean ΔL, Δa, Δb values before and after the accelerated ageing for all the groups along with the mean colour change (ΔE) are summarised in the [Table/Fig-2]. The mean colour changes observed in the Group I (etch wash-dual cure) was highest with ΔE at 2.491. The Group II (etch wash-light cure) and Group III (self-etch) had mean ΔE value at 1.110 and 2.357 respectively. The Group IV (self–adhesive) presented the lowest colour change (ΔE) values at 0.614. The results of ANOVA [Table/Fig-2] showed the statistically significant difference in ΔE among the luting cements tested in the study with a p-value at 0.041.

The statistical analysis with LSD post-hoc multiple comparison test [Table/Fig-3] showed the presence of statistically significant difference between etch wash-dual cure cement (Group I) and self-adhesive cement (Group IV) with a p-value of 0.017. The statistical analysis also revealed the presence of the significant difference between self-adhesive (Group IV) and self-etching cement (Group III) (p=0.026).

Group	Tooth conditioning	Manufacturer	Steps of application
I	Etch wash -dual cure	Rely X ARC, 3M ESPE, St. Paul, USA	Surface etching with 37% phosphoric acid for 20 seconds, Rinsed with water and blot dried, self-priming adhesive was applied for 20 seconds and light cured for 20 seconds, dual cure.
II	Etch wash -Light cure	Variolink Veneer, Ivoclar Vivadent AG, Bendererstrasse, Liechtenstein	Surface etching with 37% phosphoric acid for 20 seconds, Rinsed with water and blot dried, self-priming adhesive was applied for 20 seconds and light cured for 20 seconds, light cure.
III	Self-etch	Panavia F 20, Kuraray Medical Inc, Okayama, Japan	Single step, self-etch; mixing of an equal amount of primer A and B. The mixture was applied to the tooth surface with light rubbing action for 20 seconds and gently air dried. Mix equal amounts of paste A and B for 20 seconds, apply mixture on to the veneer, light cure for 20 second and apply oxyGuard.
IV	Self-adhesive	Rely X unicement, 3M ESPE, St. Paul, USA	No preconditioning of tooth surface, the activation of capsule, 15 second mixing in amalgamator, apply on to veneer, self cure for 2-3 min and light cure for 20 seconds.

[Table/Fig-1]: Description of the groups, materials and tooth conditioning used in the study.

Groups	ΔL		Δa		Δb		ΔE
	Before	After	Before	After	Before	After	
Group I	1.744	4.346	0.234	0.102	-1.486	4.505	2.491(1.746)
Group II	0.753	1.890	0.123	0.050	-0.807	2.170	1.110(1.788)
Group III	0.560	4.727	0.503	0.458	-1.066	3.26	2.357 (1.793)
Group IV	-0.417	0.905	0.093	0.196	0.150	0.865	0.614(1.328)
ANOVA results: F =3.054, p= 0.041*.							

[Table/Fig-2]: Mean ΔL, Δa, Δb and mean colour change (ΔE) values before and after the accelerated ageing for all the groups and ANOVA for mean colour change (ΔE).
* The mean difference is significant at the 0.05 level.

DISCUSSION

The increased expectation of aesthetic outcome of the society has led to the wider application of ceramic laminates in modern dentistry.

Multiple comparisons						
Mean colour change (ΔE) LSD		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
GROUP	GROUP				Lower Bound	Upper Bound
EW-DC	EW-LC	1.3810828	0.7493330	0.074	-0.138635	2.900801
	SE	0.1340591	0.7493330	0.859	-1.385659	1.653777
	SA	1.8771886*	0.7493330	0.017*	0.357471	3.396906
EW-LC	EW-DC	-1.3810828	0.7493330	0.074	-2.900801	0.138635
	SE	-1.2470237	0.7493330	0.105	-2.766742	0.272694
	SA	0.4961058	0.7493330	0.512	-1.023612	2.015824
SE	EW-DC	-0.1340591	0.7493330	0.859	-1.653777	1.385659
	EW-LC	1.2470237	0.7493330	0.105	-0.272694	2.766742
	SA	1.7431295*	0.7493330	0.026*	0.223412	3.262847
SA	EW-DC	-1.8771886*	0.7493330	0.017*	-3.396906	-0.357471
	EW-LC	-0.4961058	0.7493330	0.512	-2.015824	1.023612
	SE	-1.7431295*	0.7493330	0.026*	-3.262847	-0.223412

[Table/Fig-3]: Post-hoc LSD comparison of the mean colour change between different group pair.
*. The mean difference is significant at the 0.05 level. EW-DC: etch wash-dual cure (Group I), EW-LC: etch wash-light cure (Group II), SE:Self-etch (Group III), SA: self-adhesive (Group IV)-

The colour of the restoration in harmony with adjacent natural teeth and its permanency are important criteria for the satisfactory aesthetic outcome. The resin cements with different adhesive strategy and polymerization techniques are routinely used for the luting purpose. The dentin substrate underneath the composite resin cement is composed of hybrid layer [15]. The hybrid layer consists of polymerized monomer and demineralized collagen resulting from adhesive treatment [16]. The structural integrity of hybrid layer components plays a significant role in the luting cement colour. The tooth samples in this study were subjected to the accelerated ageing to anlyse the effect of different adhesive bonding techniques on the colour stability of luting cements used in the PLV. In the present study, the spectrophotometer was used to identify the colour, since it is considered as more objective, quantifiable and superior to visual method [17]. The Vita Easy shade used in the study consists of embedded fiber-optic light source at the instrument tip. Hence, the influence of external light and its induced colour changes due to metamerism were excluded. The colour was recorded in CIELAB system. It has multiple advantages; it includes all perceivable colours, device independence, perceptual uniformity similar to human perception and ability to denote the colours in numerical units. The in vitro ageing process of composites resin cements was achieved by immersion in the water and thermocycling to simulate the oral environment. Researchers, furthermore, advocated the xenon light exposure in controlled temperature to evaluate the colour stability for resin cement [18].

All the tested adhesive systems during the study showed the colour changes to varying degree. Among the tested adhesive system, etch-wash dual cure luting cement recorded the highest mean colour (ΔE) change. This study confirms the observation from earlier studies that the dual cure resins have more ageing induced colour changes in comparison to light cure resins [19,20]. The increased colour changes can be attributed to multiple factors like degradation of residual amines, and oxidation of remaining unreacted carbon double bonds. These structural changes in the cement lead to the formation of yellow compound. Etch wash-light cure resin cement had lesser mean colour change (ΔE) at 1.110. Previous researchers have also found better colour stability of the light cure cements [21]. The aliphatic amines are used as polymerization initiators in light cure resins. The aromatic tertiary amines have more tendencies for oxidization than the aliphatic amines. Hence, the light cure resins are reported to have better colour stability [8].

The colour changes are also attributed to the properties of the resin matrix and filler salinization [22]. The water absorption is mainly influenced by the polarity of monomer like methacrylate, TEGDMA and UDMA with polar functional groups like carboxyl, phosphate, hydroxyl in Bis-GMA and HEMA [23]. The water absorption results in disruption of interchain hydrogen bonding of polymer matrix [24]. The altered molecular change results in the altered refractory index. The dentin bonding surface adjoining the margins of the restorations are exposed to saliva and other oral fluids. The dentin fluid within the dentinal tubules is also likely to interact with the adhesive agents. Both water absorption and the degradation of the adhesive lead to the discolouration of the bonded area. The total etch and wash procedure removes all inorganic content in dentin matrix and produces the lower surface tension at the dentin surface. Hence, it may lead to more water absorption during the ageing process.

Self-etch adhesives have become popular among the dentist due to quick and easy manipulation steps. The self-etch adhesives rely upon both on micro-mechanical interlocking and chemical bonding to the functional monomers [25]. The ΔE value for the self-etching adhesive was comparatively less than etch-wash dual cure resin cement. The self-etch adhesive has pH values of 1-2. Though, smear layer is not completely removed, the low pH results in deep demineralisation. The higher constituent hydrophilic monomers, lower carbon-carbon double bond conversion in self-etch adhesive contributes to the higher water absorption, greater degradation process [26] and consequent colour change.

The benefit of self-adhesive cements is quick and simple application procedure, as it requires no preconditioning of the tooth structure. This dentin bonding technique showed the least mean colour change (ΔE). The acid functionalised monomers are utilised to accomplish the demineralisation and bonding to the tooth structure [27]. Predominantly used acid functionalised monomer in the cement is methacrylate monomer with carboxylic or phosphoric acid groups. The pH of acidic monomer is balanced to avoid excessive hydrophilicity in final polymer and to achieve sufficient self –etching character. The polymerisation reaction lead to increased hydrophobicity as the acid functionality is neutralised with calcium in tooth structure and other metal oxides in filler [28]. The swelling and discolouration of the polymer are less due to the hydrophobic nature of the final set polymer.

Many researchers are of the opinion that the colour changes (ΔE) less than 3.5 is imperceptible and clinically acceptable [29,30]. The mean colour changes observed among all the groups in the present study were lower than 3.5. The limitations of the study include the small sample size, and the exact simulation of ageing in oral cavity is difficult to replicate. The effect of other external factors like dietary colours, plaque accumulation, and exposure to the various pH environments was not considered. Further studies are required to analyse the colour changes using different shades of luting cements, and effect of different levels pH fluids on mean colour changes.

CONCLUSION

Within the limitation of the present in vitro study, following conclusions were drawn:

1. All adhesive techniques evaluated during the study showed the significant mean colour change after the accelerated ageing process;
2. Post accelerated ageing, the etch wash-dual cure techniques exhibited highest mean colour changes; the self-adhesive cements showed the best colour stability;
3. The statistically significant difference in mean colour change was observed between self-adhesive cement and etch wash-dual cure; and self-adhesive and self-etch luting cements;
4. All the tested luting techniques had the colour changes within the clinical acceptable level of less than 3.5.

REFERENCES

[1] Beier US, Kapferer I, Burtscher D, Dumfahrt H. Clinical performance of porcelain laminate veneers for up to 20 years. Int J Prosthodont. 2012;25(1):79-85.
[2] Guazzato M, Albakry M, Ringer SP, Swain MV. Strength, fracture toughness and microstructure of a selection of all-ceramic materials. Part I. Pressable and alumina glass-infiltrated ceramics. Dent Mater. 2004;20(5):441-48.
[3] Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part II: core and veneer materials. J Prosthet Dent. 2002;88(1):10-15.
[4] el-Mowafy O. The use of resin cements in restorative dentistry to overcome retention problems. J Can Dent Assoc. 2001;67:97-102.
[5] Gurdal P, Akdeniz BG, Hakan Sen B. The effects of mouthrinses on microhardness and colour stability of aesthetic restorative materials. J Oral Rehabil. 2002;29(9):895-901.
[6] Samra AP, Pereira SK, Delgado LC, Borges CP. Colour stability evaluation of aesthetic restorative materials. Braz Oral Res. 2008;22(3):205-10.
[7] Imazato S, Tarumi H, Kobayashi K, Hiraguri H, Oda K, Tsuchitani Y. Relationship between the degree of conversion and internal discolouration of light-activated composite. Dent Mater J. 1995;14(1):23-30.
[8] Asmussen E. Factors affecting the colour stability of restorative resins. Acta Odontol Scand. 1983;41(1):11-18.
[9] Eliades T, Gioka C, Heim M, Eliades G, Makou M. Colour stability of orthodontic adhesive resins. Angle Orthod. 2004;74(3):391-93.
[10] Musanje L, Shu M, Darvell BW. Water sorption and mechanical behaviour of cosmetic direct restorative materials in artificial saliva. Dent Mater. 2001;17(5):394-401.
[11] Iwami Y, Yamamoto H, Sato W, Kawai K, Torii M, Ebisu S. Weight change of various light-cured restorative materials after water immersion. Oper Dent. 1998;23:132–37.
[12] Kucukesmen HC, Usumez A, Ozturk N, Eroglu E. Change of shade by light polymerization in a resin cement polymerized beneath a ceramic restoration. J Dent. 2008;36(3):219-23.
[13] Archegas LR, Freire A, Vieira S, Caldas DB, Souza EM. Colour stability and opacity of resin cements and flowable composites for ceramic veneer luting after accelerated ageing. J Dent. 2011;39(11):804-10.
[14] Turgut S, Bagis B. Colour stability of laminate veneers: An in vitro study. J Dent. 2011;39 Suppl 3:e57-64.
[15] Van Meerbeek B, Vargas S, Inoue S, Yoshida Y, Peumans M, Lambrechts P, et al. Adhesives and cements to promote preservation dentistry. Oper Dent (Supplement 6). 2001;26:119-44.
[16] Nakabayashi N, Nakamura M, Yasuda N. Hybrid layer as a dentin-bonding mechanism. J Esthet Restor Dent. 1991;3(4):133-38.
[17] Kourtis SG, Tripodakis AP, Doukoudakis AA. Spectrophotometric evaluation of the optical influence of different metal alloys and porcelains in the metal-ceramic complex. J Prosthet Dent. 2004;92(5):477-85.
[18] Kilinc E, Antonson SA, Hardigan PC, Kesercioglu A. Resin cement colour stability and its influence on the final shade of all-ceramics. J Dent. 2011;39 Suppl 1:e30-36.
[19] Noie F, O'Keefe KL, Powers JM. Colour stability of resin cements after accelerated aging. Int J Prosthodont. 1995;8(1):51-55.
[20] Nathanson D, Banasr F. Colour stability of resin cements--An in vitro study. Pract Proced Aesthet Dent. 2002;14(6):449-55.
[21] Hekimoglu C, Anil N, Etikan I. Effect of accelerated aging on the colour stability of cemented laminate veneers. Int J Prosthodont. 2000;13(1):29-33.
[22] Topcu FT, Sahinkesen G, Yamanel K, Erdemir U, Oktay EA, Ersahan S. Influence of different drinks on the colour stability of dental resin composites. Eur J Dent. 2009;3(1):50-56.
[23] Ito S, Hashimoto M, Wadgaonkar B, Svizero N, Carvalho RM, Yiu C, et al. Effects of resin hydrophilicity on water sorption and changes in modulus of elasticity. Biomaterials. 2005;26(33):6449-59.
[24] Ping ZH, Nguyen QT, Chen SM, Zhou JQ, Ding YD. States of water in different hydrophilic polymers — DSC and FTIR studies. Polymer. 2001;42(20):8461-67.
[25] Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, Van Landuyt KL. State of the art of self-etch adhesives. Dent Mater. 2011;27(1):17-28.
[26] Tay FR, Pashley DH. Have dentin adhesive become too hydroplilic? J Can Dent Assoc. 2003;69:726–31.
[27] Van Landuyt KL, Yoshida Y, Hirata I, Snauwaert J, De Munck J, Okazaki M, et al. Influence of the chemical structure of functional monomers on their adhesive performance. J Dent Res. 2008;87:757–61.
[28] Yoshida Y, Nagakane K, Fukuda R, Nakayama Y, Okazaki M, Shintani H, et al. Comparative study on adhesive performance of functional monomers. J Dent Res. 2004;83(6):454-58.
[29] Ruyter IE, Nilner K, Moller B. Colour stability of dental composite resin materials for crown and bridge veneers. Dent Mater. 1987;3(5):246-51.
[30] Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colourimetry. J Dent Res. 1989;68(5):819-22.

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