Review Article

A comparison of the marginal and internal fit of CAD/CAM fabricated metal alloy fixed partial dentures

Mohd Faiz Nasruddin[1], Antonios Theocharospoulos[2], Noel Ray[2], Francis M Burke[2]

[1]*Center of Comprehensive Care Studies, Faculty of Dentistry, Universiti Teknologi MARA, Sungai Buloh Campus, 47000 Selangor, Malaysia.*

[2]*Restorative Dentistry, Cork University Dental School and Hospital, Wilton, Cork, Ireland.*

Keywords: Fit, CADCAM, fixed partial dentures, FPD, review

DOI: https://doi.org/10.24191/cos.v3i0.17514

Background

Fitting accuracy of dental prostheses is essential for clinical success. An ideal marginal and internal fit will minimize plaque accumulation, gingival irritation, cement dissolution and micro leakage as well as enhancing the mechanical behaviour of a fixed partial denture (FPD) (1). Unfortunately, there is disagreement about acceptable marginal and internal fit discrepancies of FPD's (2) from 75-200µm. The range of discrepancies stated (75-200µm) does not jeopardize the clinical performance of the restoration. However, McLean and von Fraunhofer (3) reported that marginal gaps of less than 120µm are clinically acceptable while gaps of less than 80µm are difficult to detect clinically.

The conventional method of fabrication of FPD's is the lost wax method. The method involves making a suitable cast of the patient's mouth, creating a wax template of the FPD framework on the cast, creating a mould of the wax template and casting metal alloy into the mould after the wax has been eliminated. This technique has been a popular approach for FPD framework fabrication for decades (1). The fact however that it involves several technique sensitive steps and a variety of materials makes the control of the restoration fitting accuracy problematic.

Recent advances in manufacturing technology have introduced Computer Aided Design/ Computer Assisted Manufacturing (CAD/CAM) methods for the fabrication of FPD's. Several conventional steps of fabrication are eliminated using these methods. The CAD/CAM approach has three main processes in fabricating an FPD; the digitising process, the designing process and the manufacturing process. Although each process is important, emphasis has been placed on the manufacturing stage as fit of product is dependent on the ability of the system to create the desired prosthesis.

There are two main manufacturing routes of CAD/CAM FPD's: the subtractive and the additive route. The subtractive route is a top-down approach which involves milling the desired article out of a block of the material of choice using a series of burs. This route is currently the most common CAD/CAM technique for the fabrication of metal alloy FPD's. The additive route is a bottom-up approach where the desired article is fabricated layer by layer out of the material of choice. Examples include selective laser sintering and selective laser melting for metal alloy FPD's.

The potential of CAD/CAM fabricated prostheses in respect to fit accuracy is gaining interest. Much has been documented about the importance of the accuracy of fit for a successful CAD/CAM fabricated FPD (5-9). While the literature on the fit of CAD/CAM generated FPD's is quite extensive, the technology is seen to be advancing quickly thus creating a need for regular updating of information (10).

To our knowledge few CAD/CAM studies have been done in relation to dental alloys (2, 11-17). Alloys in dentistry are considered an important

*Corresponding to: Dr Mohd Faiz Nasruddin.
Center of Comprehensive Care Studies, Faculty of Dentistry, Universiti Teknologi MARA, Sungai Buloh Campus, 47000 Selangor, Malaysia.
E-mail: drfaiz@salam.uitm.edu.my
Tel: +6019-6677966

material to date and is increasingly gaining popularity (18). High strength ceramics are mostly recommended for normal interocclusal clearance cases. While metal or resins are alternative restoration options, metal ceramic is considered the best option where a combination of strength and aesthetics is necessary (19-21). While a systematic review of the fit of zirconia FPDs has been published before (8), no review has been published to date on the fit of CAD/CAM fabricated metal alloys in fixed partial dentures (FPDs).

Problem statements

1. Based on the apparent lack of relevant studies to date, it appears that a systematic review on the fit of CAD/CAM fabricated metal alloy FPD's would be useful.
2. Comparisons between both subtractive and additive methods of CAD/CAM have not been properly investigated.
3. A direct comparison with CAD/CAM methods and the lost wax technique would be benficial for readers.

Objectives

The aim of this study is to systematically review the fit of CAD/CAM fabricated metal alloy crowns and bridges.

Methodology

Search strategy

A summary of the search strategy is presented in Figure 1. The search for literature was primarily based on an electronic search through MEDLINE via the PubMed database. Using Boolean operators, the following keywords were combined: 'fit', 'marginal', 'internal', 'computer aided design', 'computer assisted manufacturing', 'CAD/CAM', 'CAD CAM', 'coping',' crown', 'fixed partial denture', 'fixed dental prosthesis', 'framework', 'alloy', 'metal', 'titanium' and 'cobalt chrome'. Similarly, keywords were used for an electronic search in the Scopus database, Academic Search Complete database, Science Direct database and Web of Knowledge database. No restrictions were performed regarding the publication date up to August 2016. All abstracts were read and inclusion criteria (Table1) were used to eliminate papers irrelevant to this systematic review. Selected papers were analysed and the main findings are presented here. Manual search of references in each paper was performed to find potential papers which fulfil the selected criteria.

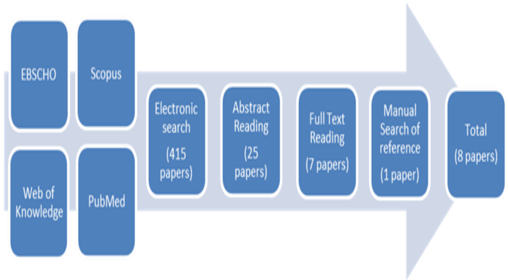


Figure 1: Search strategy of papers selected

Criteria

Inclusion criteria are presented in Table 1. One paper was eliminated as it was not presented in English (22). Papers included concerned metal alloy FPD's constructed by the CAD/CAM method. Both *in vitro* and *in vivo* studies were investigated. Only papers that evaluated and measured fit were used. The definition of fit is illustrated in Figure 2. A vertical marginal fit is defined as the distance between the restoration and the preparation when measured parallel to the long axis of the tooth (23). A horizontal marginal fit is defined as the distance between the restoration and the preparation when measured perpendicular to the long axis of the tooth (23). For this study the axial wall internal fit is defined as the perpendicular distance from the axial wall of the tooth to the restoration and occlusal fit is the perpendicular distance from occlusal wall of the tooth to the restoration. For papers not specifying on the site of internal fit, mean internal fit is displayed.

Study description

A total of 415 papers were initially found using the electronic search. Twenty five papers were then selected after reading the abstracts and applying the inclusion criteria. Seven papers were finally selected after studying the 25 papers and applying the inclusion criteria. Manual search of the references within the selected

Selected Criteria	
Publication type	Published/Peer reviewed
Language	English
Necessary content	FPD must be fabricated by CAD/CAM Fit assessment
Type of study	*In vivo/In vitro* studies
Type of FPD	Single coping/Bridge framework
Material	Metal alloys

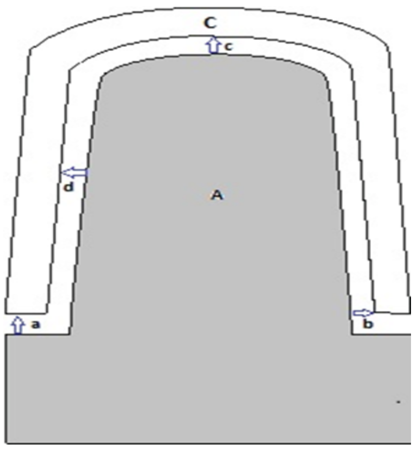
Table 1: Inclusion criteria for the Review

papers identified one more paper in agreement with the inclusion criteria. A total of eight papers were therefore used for the systematic review (Figure 1).

Results

A summary of the selected studies is presented in Table 3. Six selected papers (11-16) were *in vitro* studies and two had both *in vitro* and *in vivo* results (2, 17); five assessed only marginal fit of alloys (2, 11, 13, 16, 17), two assessed internal fit (12, 14) and Han *et al.* 2011 assessed both internal and marginal fit of metallic frameworks to their abutment (15). Witkowski *et al.* 2006 assessed the horizontal marginal fit of alloy coping (16) while six others assessed the vertical fit (2, 11, 13, 15-17). Two studies showed the total internal fit (12, 14) and Han *et al.* 2011 showed the occlusal and axial internal fit (15).

The majority of alloy frameworks were fabricated using milling machines (subtractive route). Three studies had results for fabrication by laser sintering (12, 14, 17) (additive route). The results include fit assessment carried out on parts fabricated by the following CAM systems (Table 2):



A: Tooth abutment; C: Coping; a: Vertical marginal fit; b: Horizontal marginal fit; c: Occlusal internal fit; d: Axial internal fit

Figure 2: Illustration of marginal and internal fit

System	Manufacturer	Origin
PM100 Dental System	PHENIX Systems	France
DC-Titan	DCS Dental	Switzerland
Everest	Kavo Dental GMbH	Germany
Modified I-Mes Premium 4820	I-Mes Wieland	Germany
Procera	Nobel Biocare AB	Sweden
3.3.2.3	KaVo	USA
Pro 50 CAM	Cynovad	Canada
Precimill	DCS Dental AG	Switzerland
BEGO Medifacturing-system	BEGO Medical	Germany

Table 2: CAM systems in selected studies

Discussion

Methods for measuring fit varied in these studies. At present, there are no fit assessment standards (ISO or others). In summary, the methodologies utilised were:

1. Cementation of the dental prosthesis on a master cast with silicone/dental cements followed by sectioning and subsequent measurement with stereomicroscope.
2. Stabilization (pin/loading jig) of dental prosthesis on master cast followed by digital photography of marginal adaptation and analysis with measurement software.

The results of fit of CAD/CAM fabricated alloy FPD's and the conventional method of lost-wax method of all selected studies are displayed in Table 3. Two studies favoured the CAD/CAM over the lost-wax method of fabrication (11, 16) while 3 showed the opposite (12, 13, 15). Ortorp *et al.* 2011 favoured the fit of laser sintered over milled prostheses (12) and Quante *et al.* 2008 favoured fabrication of dental prostheses in gold over cobalt chrome (17). Results were classified to factors that influenced fit of alloys by CAD/CAM:

1. Fabrication system
2. Alloy type
3. Examination methods

Two studies (2, 17) did not show results of fit of prosthesis via the traditional lost wax method but only displayed results of CAD/CAM fabrication. All studies demonstrated the use of CAD/CAM or at least Computer Assisted Manufacturing (CAM) in metal alloy prostheses fabrication. Papers selected used controls that utilize the same material to what was used for the intervention. Materials include cobalt chrome and titanium. Sample sizes of papers selected ranged from 5-20. Ucar *et al.* (2009) was the only paper that did not specify the prostheses type utilised in their study.

There seems to be consensus among authors that CAD/CAM technology is a promising field. However variations between values obtained from different studies, make it impossible to rank CAD/CAM and the conventional lost-wax method. More research could be done to address this matter. The search of papers revealed many studies showing fabrication of dental prosthesis with CAD/CAM, however only few used metal alloys for fabrication. This review only looked at FPD excluding implants; this led to elimination for other type of frameworks related to dentistry. Implant supported FPD related papers were also excluded.

Sample size used in selected studies ranged from 5-20 specimens. Two studies (2, 15) made repeated measurements at specific points on specimens. This however may influence results. The Ortorp *et al.* (2011) paper had high standard deviations, results suggesting an increase in sample sizes would have been beneficial.

Table 3 Summary of selected studies

Referance		Methodology					Results					
		Examination method	System				Sample size	Marginal Fit µm(S.D)		Internal Fit µm(S.D)		
No.	Author and Date		Manufacturer	Protheses type	Fabrication type	Alloy type		Vertical	Horizontal	Axial	Occlusal	Mean
1	Ucar et al. 2009	Optical microscope-SZ40; Olypus, Tokyo, Japan) then analysed with ImageJ and NIH Image software; National Institute of Helath, Bethesda, Md	PM100 Dental System; PHENIX Systems, France	Crown (not specified)	Lost Wax	Cobalt Chrome	12					50.6(25.1)
					Laser-sintered		12					62.6(21.6)
2	Romeo et al. 2009	Stereo microscope; Wild M5A, Heerbrugg, Switzerland-50X then analysed with Image J 1.32, US National Institues of Health, Bethesda, MA, USA	DC-Titan; DCS Dental, Switzerland	Crown coping	Milled	Titanium	5	20.3(6.7)				
							5	12.6(4.6)				
3	Han et al. 2011	Measuring microscope; Mituyo America Corp, Aurora, III-30X and SEM, JSM-7500F; JEOL, Tokyo, Japan-50X	Everest, Kavo Dental GmbH, Germany	Crown coping	Lost Wax	Titanium	20	52.2(14.2)		67.5(20)	109.8(32.9)	
					Milled		20	59.8(14.9)		51(10.8)	124.6(28)	
4	Shokry et al. 2010	Stereo microscope;Axioskop; Carl Zeiss Microimaging, Inc, Gottinen, Germany then analysez with ImageJ, v,1.37, NIH, Bethesda, Md.	Everest; Kavo Dental GMbH, Biberach, Germany	Crown coping	Lost Wax	Titanium	5	81.5(10.7)				
					Milled		5	24.1(1.9)				
5	Ortorp et al. 2011	Stereo microscope; Wild M7A, Wild Heerbrugg LTD, Heerbrugg, Switzerland then analysed with Leica Application Suite v. 3.3.1, Leica Microsystem GmbH		Bridge framework	Lost Wax	Cobalt Chrome	8					133(89)
			Modified I-Mes Premium 4820, I-Mes Wieland, Germany		Milled		8					166(135)
			Procera; Biomain AB, Helsinborg, Sweden		Laser-sintered		8					84(60)
6	Tan et al. 2007	Canon 10D 100-mm macro lens, Canon USA, Inc., Lake Success, NY then analysed with Image Pro Plus version 2.0, Media Cybernetics, Silver Spring, MD	3.3.2.3, KaVo, USA	Crown coping	Lost Wax	Titanium	10	23.9(9.8)				
					Milled		10	79.4(25.5)				
7	Witkowski et al. 2006	Stereomicroscope (Axioskop; Zeiss. Oberkochen, Germany then analysed with analySIS 2.1; soft imaging software GmbH, Munster, Germany		Crown coping	Lost Wax	Titanium	16	43.6(25.6)	18.7(13.6)			
			Pro 50 CAM, Cynovad		Milled		16	23.9(6.7)	36.7(20.9)			
			Precimill; DCS Dental AG				16	7.8(6)	10.1(5.5)			
			Everest; KaVo Dental GmbH				16	38.4(18.2)	38.8(12)			
8	Quante et al. 2007	Light microscope; M420, Wild, Netherlands then analysed with Leica Manager; Leica, UK	BEGO Medifacturing-system, BEGO medical, Germany	Crown coping	Laser-melting	Cobalt Chrome	14	93				
			BEGO Medifacturing-system, BEGO medical, Germany		Laser-melting	Gold Platinum	14	73				

Fabrication system

Ucar *et al.* (2009) stated that the laser sintering process provides promising fit results, comparable to the lost wax method. The study laser sintered a CoCr and had two controls of conventional fabrication of CoCr and NiCr. No significant difference was found between methods. The use of finger pressure for coping cementation prior to fit evaluation is however of concern as it may have introduced a systematic error in the internal fit measurement.

Ortorp *et al.* 2011 found laser sintering produced significantly ($p<0.05$) better vertical and marginal fit when compared to milling (12). In their study different techniques were compared in vitro: conventional casting, milled wax and casting, milled CoCr and laser sintered CoCr. There was no significant difference found when laser sintering was compared to the lost-wax technique. However when milling was compared to the lost-wax technique, results favoured the conventional ($p< 0.05$). The paper compared bridge framework designs on premolars and molars as abutments. Considering the design had two coping abutments that have the same points to be analysed. The conclusion; mean of internal and marginal fit between the two different abutments would not have been possible.

The conventional method for fabrication of dental prostheses is the lost-wax method. Reports (Table 3) suggest that this method is able to fabricate alloy FPD's well within accepted clinical fit (17). For this review, the lost-wax method is considered the benchmark for methods of fabrication. However, van Noort (2012) states that the future of dentistry lies with CAD/CAM technology (10). With advantages of quick fabrication, reliable results and ability to create complex designs (10) makes us wonder if the lost wax technique could be replaced. Nevertheless, until concrete evidence is displayed; the lost-wax method still remains integral part of dental prostheses fabrication.

Contradictory results have been identified as some studies favour conventional versus CAD/CAM techniques (12, 13, 15) and vice versa (11, 16) in respect to fit. However, all papers agree that milling with CAD/CAM is promising as marginal discrepancies were all within an acceptable range. Tan *et al.* 2007 may have incorporated a biased methodology that can influence results. Author had manually applied 4 layers of die spacer for the conventional method but did not state the thickness of the die spacer. 80μm of die spacer was applied for the CAD/CAM group. Differences in die spacer thickness may have had an influence in results.

Variability in tools involved makes it difficult to rank the systems in terms of accuracy of fit. Most manufacturers use the subtractive routes but variation in different tools used for the milling procedure again disallows the use of a proper meta-analysis. The diameter of cutting burs used for milling varies from a 0.8-1.0mm (16). To our knowledge, there is no such evidence stating that size of burs has an effect on fit. However it may be a potential limitation.

Limitations also occur as scanner systems and software for designing used in the selected papers differ. The variation it poses, although less important as this review only presents the outcome of the FPD's could have influence on results. Future research to minimize variability's is there for suggestion.

Alloy type

Quante *et al.* (2008) found that the type of alloy used to fabricate CAD/CAM prostheses does not affectthe marginal fit. Within the investigated studies, three alloys were used with different systems namely titanium, cobalt chrome and gold platinum. Titanium appears to have better fit (Table 3), however due to inter-measurement variability, this outcome would need to be investigated further.

Examination methods

Marginal and internal fit evaluation required cementing of prosthesis on to master cast. Various dental cements were used to stabilize the prosthesis and measurement of thickness of cement would provide fit. Sectioning however meant that copings would have to be destroyed. The silicon replica technique could be an alternative to the methods. This technique involved applying low viscosity silicone on internal surfaces of coping and applying load on to cast. After setting of silicone, high viscosity silicone is applied over the set putty for stabilisation and measurement of low viscosity putty gives the fit of restoration. Validation of non-destructive technique has been done and results were comparable to the use of zinc phosphate cement (24).

Four papers (2, 11, 13, 16) used external microscopic examination with the utilisation of cameras and measuring software. However, this method has its limitation in being able to measure fit of marginal opening only if sectioning was not performed. If it was done, a method to stabilize prostheses in cast would have to be applied.

There are no standard methods of evaluation of fit yet to date. Consequently, a variability in measurement systems is noticed and could well affect results. Most ISO standards directed towards dentistry is looking at health and safety issues (25). There is none to be found on measurement and accuracy of CAD/CAM systems. Currently, development in ISO standards of the system is still in progress. Until a standard methodology is created, variations of results will continue to be displayed in research.

Conclusion

Within the limitations of this review, the following conclusions may be drawn with regard to the use of CAD/CAM techniques in the fabrication of FPDs:

1. Results for marginal fit of metal alloy FPD's ranging from 7.8-93μm and internal fit ranging from 50.6-166μm suggest that CAD/CAM methodology may be appropriate to generating a clinically acceptable fit in metal alloy FPD's.
2. Variations exist in the method of determining accuracy of fit indicating the need for an ISO standard as this will allow a proper meta-analysis to be carried out.
3. Variations in study don't allow a conclusion to favour CAD/CAM over the conventional method. The conventional lost-wax techniques remain an appropriate method of fabricating dental prostheses.

Reference

1. Abduo J, Lyons K, Swain M. Fit of zirconia fixed partial denture: a systematic review. ***J Oral Rehabil. 2010.*** **37(11),** 866-76. Epub 2010/06/19.

2. Romeo E, Iorio M, Storelli S, Camandona M, Abati S. Marginal adaptation of full-coverage CAD/CAM restorations: in vitro study using a non-destructive method. ***Minerva stomatologica. 2009.*** **58(3),** 61-72. Epub 2009/04/10.

3. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. ***British Dent Journal. 1971.*** **131(3),** 107-11. Epub 1971/08/03.

4. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. ***British Dental Journal. 2008.*** **204(9),** 505-11.

5. Andersson M, Carlsson L, Persson M, Bergman B. Accuracy of machine milling and spark erosion with a CAD/CAM system. ***The Journal of Prosthetic Dentistry. 1996.*** **76(2),** 187-93. Epub 1996/08/01.

6. Coli P, Karlsson S. Fit of a new pressure-sintered zirconium dioxide coping. ***The International Journal of Prosthodontics. 2004.*** **17 (1),** 59-64. Epub 2004/03/11.

7. Grenade C, Mainjot A, Vanheusden A. Fit of single tooth zirconia copings: comparison between various manufacturing processes. ***Journal of Prosthetic Dentistry. 2011.*** **105(4),** 249-55.

8. Abduo J, Lyons K, Swain M. Fit of zirconia fixed partial denture: a systematic review. ***Journal of Oral Rehabilitation. 2010.*** **37(11),** 866-76.

9. Kohorst P, Brinkmann H, Li J, Borchers L, Stiesch M. Marginal accuracy of four-unit zirconia fixed dental prostheses fabricated using different computer-aided design/computer-aided manufacturing systems. ***European Journal of Oral Sciences. 2009.*** **117(3),** 319-25. Epub 2009/07/09.

10. van Noort R. The future of dental devices is digital. ***Dental materials. 2012.*** **28(1)**, 3-12. Epub 2011/11/29.

11. Shokry TE, Attia M, Mosleh I, Elhosary M, Hamza T, Shen C. Effect of metal selection and porcelain firing on the marginal accuracy of titanium-based metal ceramic restorations. ***Journal of Prosthetic Dentistry. 2010.*** **103(1),** 45-52.

12. Örtorp A, Jönsson D, Mouhsen A, Vult

von Steyern P. The fit of cobalt–chromium three-unit fixed dental prostheses fabricated with four different techniques: A comparative in vitro study. ***Dental Materials. 2011.*** **27(4),** 356-63.

13. Tan PL, Gratton DG, Diaz-Arnold AM, Holmes DC. An in vitro comparison of vertical marginal gaps of CAD/CAM titanium and conventional cast restorations. ***Journal of Prosthodontics. 2008.*** **17(5),** 378-83.

14. Ucar Y, Akova T, Akyil MS, Brantley WA. Internal fit evaluation of crowns prepared using a new dental crown fabrication technique: laser -sintered Co-Cr crowns. ***The Journal of prosthetic dentistry. 2009.*** **102(4),** 253-9. Epub 2009/09/29.

15. Han HS, Yang HS, Lim HP, Park YJ. Marginal accuracy and internal fit of machine-milled and cast titanium crowns. ***The Journal of Prosthetic Dentistry. 2011.*** **106(3),** 191-7. Epub 2011/09/06.

16. Witkowski S, Komine F, Gerds T. Marginal accuracy of titanium copings fabricated by casting and CAD/CAM techniques. ***The Journal of Prosthetic Dentistry. 2006.*** **96(1),** 47-52. Epub 2006/07/29.

17. Quante K, Ludwig K, Kern M. Marginal and internal fit of metal-ceramic crowns fabricated with a new laser melting technology. ***Dental materials. 2008.*** **24(10),** 1311-5. Epub 2008/04/04.

18. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. ***The Journal of Prosthetic Dentistry. 2002.*** **88(1),** 4-9. Epub 2002/09/20.

19. Boushell LW, Ritter AV. Ceramic inlays: a case presentation and lessons learned from the literature. ***Journal of Esthetic and Restorative Dentistry. 2009.*** **21(2),** 77-87. Epub 2009/04/17.

20. Conrad HJ, Seong WJ, Pesun IJ. Current ceramic materials and systems with clinical recommendations: a systematic review. ***The Journal of Prosthetic Dentistry. 2007.*** **98(5),** 389-404. Epub 2007/11/21.

21. Raigrodski AJ. Contemporary materials and technologies for all-ceramic fixed partial dentures: a review of the literature. ***The Journal of Prosthetic Dentistry. 2004.*** **92(6),** 557-62. Epub 2004/12/08.

22. Denissen HW, van der Zel JM, van Waas MA. [CAD/CAM-copings for partial coverage]. ***Nederlands tijdschrift voor tandheelkunde. 1999.*** **106(2),** 38-41. Epub 2002/04/05. CAD/ CAM-copings voor partiele omslijpingen.

23. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. ***The Journal of Prosthetic Dentistry. 1989.*** **62(4),** 405-8. Epub 1989/10/01.

24. Laurent M, Scheer P, Dejou J, Laborde G. Clinical evaluation of the marginal fit of cast crowns--validation of the silicone replica method. ***J Oral Rehabil. 2008.*** **35(2),** 116-22. Epub 2008/01/17.

25. Della Bona A, Wozniak WT, Watts DC. International dental standards--order out of chaos? ***Dental materials. 2011.*** **27(7),** 619-21. Epub 2011/05/13.

Original Article

Influence Of Exposure Time To Coffee On Color Stability Of Selected Composite Resin Veneers

Amar M Thiyab[1], Nik Zarina N Mahmood[2] , Mohamed Ibrahim A Hassan[3]

[1] *Primary Care Center, Faculty of Dentistry, Universiti Teknologi MARA, Sungai Buloh Campus,47000 Selangor, Malaysia.*
[2] *Centre of Comprehensive Care Studies, Faculty of Dentistry, Universiti Teknologi MARA, Sungai Buloh Campus, 47000 Selangor, Malaysia.*
[3] *Center of Studies for Restorative Dentistry, Faculty of Dentistry, Universiti Teknologi MARA, Sungai Buloh Campus, 47000 Selangor, Malaysia.*

Abstract

Objectives: The aim of the study is to evaluate the effect of the time and instant coffee solution on the color stability of three types of composite resin based veneer systems.

Materials and Methods: 24 composite resin veneer samples were selected and divided into three groups: two groups of prefabricated veneers (Edelweiss, Ultradent Inc™ (EDL) and Componeer, Coltène/ Whaledent AG^{TM} (CMP)) and one group of laboratory made (Nexco, Ivoclar Vivadent (NEX)) veneer system were tested (n=8). Specimens were prepared and stored in staining solution (instant coffee) and assessed color changes with Minolta spectrophotometer every three days for a period of 27 days, after which color differences (ΔE^*) were calculated. Data collection and analysis was done using one-way ANOVA and Student's t-test (α=0.05).

Results: One-way ANOVA revealed a significant difference in color stability between the two veneer systems. NEX group veneer system exhibited the highest color stability (ΔE^*= 0.73 ± 0.5) as compared to prefabricated veneer groups (EDL 10.07 ± 5.15, CMP 7.41 ± 4.64) with p value <0.05.

Conclusion: The color stability (ΔE^*) of the laboratory made veneer system is significantly higher than the prefabricated veneer systems and more clinically accepted.

Keywords: Laboratory made veneer, prefabricated veneer, Color stability

Introduction

The cosmetic dentistry could be referring to any dental work that improves the appearance of a person's teeth, gums and/or occlusion. It primarily focuses on improvement dental aesthetics in color, position, shape, size, alignment and overall smile appearance (Schmidt and Tatum, 2006). The minimal intervention of cosmetic dentistry provides a paradigm shift in the quality of dental care. This shift combined with the increasing demand for aesthetic front teeth that has always motivated the dentist to try newly developed materials for more conservative treatment options (Toh et al., 1987). Among the restorations used to create aesthetic results are veneers, crowns and bridges. In minimal intervention of cosmetic dentistry, veneers are commonly used to ensure conservation of tooth structure and produced aesthetic outcomes of the anterior dentition (Christensen, 2003, 2004).

Dental veneer defined as a layer of tooth-colored restorative material, usually porcelain or composite resin, attached to the surface by direct fusion, cementation or mechanical retention (Mosby, 2011). Dental veneer was used for improving the color of discolored

*Corresponding to: Dr. Amar M. Thiyab, Primary Care Center, Faculty of Dentistry, Universiti Teknologi MARA, Sungai Buloh Campus, 47000 Selangor, Malaysia.
Email:amar6652@salam.uitm.edu.my,ammaralkarkhi@yahoo.com
Tel: +6-03-61266142, +6-016-6107961

teeth and straightening slightly malpositioned teeth (Christensen, 2004). Dental veneer systems can be classified according to its material and the mode of clinical usage. The common types of veneer materials were porcelain and composite resin materials (Christensen, 2004). The mode of the clinical usage can be either direct; which is most of the time using composite resin materials, or indirect which the veneer had to be manufactured in the laboratory before its clinical usage (Affairs, 2003; Christensen, 2003, 2004). Composite resin veneer also could be classified as laboratory-made system or prefabricated system (Toh et al., 1987).

Most of the common prefabricated veneer systems were made from composite resin materials with specific polymerizing and finishing techniques (Coltene/Whaledent, 2013; Ultradent, 2012). The composite resin materials provide adequate aesthetic, high bond strength and superior mechanical properties (Rosenstiel et al., 1998). However, the shortcomings of these materials include wear, leakage and discoloration lead to impairment in the aesthetic value of the composite resin over time (Le Roux and Lachman, 2007). The discoloration of the composite resin could be due to internal and/or external factors (Rosenstiel et al., 1998). The external factors could be related to absorption and accumulation to stains (Vichi et al., 2004).

Color stability is the quality of being physically predictable, orderly, not readily moved (Mosby, 2011). Many studies have shown that composite resins are susceptible to color instability. Intrinsic and extrinsic factors were affect directly on the color stability of the composite resin veneer system. The intrinsic factors are: composition of the resin matrix, size and nature of the particles, filler loading, amount of photoinitiator or inhibitor, and the level of polymerization (Bayindir et al., 2012; Falkensammer et al., 2013; Jain et al., 2013). Meanwhile, exposure to food colorants, UV radiation, temperature changes, and water are the main extrinsic factors (Jain et al., 2013). These factors are essential in the hydrolysis and degradation of the composite resin that influenced the appearance of the materials (Asmussen, 1981; Jain et al., 2013; Vichi et al., 2004).

The instant coffee considered one of the highest consumption drinks globally. The international coffee organization stated that more than 1,896 million kg of coffee were used in Asia and Oceania in the last four years with 3.7% annual growth rate (Organization, 2016). Several studies related to color stability were confirmed the discoloration effect of the coffee on the composite resin restoration (Ertas et al., 2006; Jain et al., 2013; Turkun and Turkun, 2004). Based on that, the present study was used the instant coffee to be the staining solution beside the distilled water media.

Many studies evaluated color stability of adhesion materials related to different factors such as aging process, exposure time to staining solution, types of staining solutions and polymerization mode (dual, light or auto) (Falkensammer et al., 2013; Jain et al., 2013; Um and Ruyter, 1991; Vichi et al., 2004). However, most of the color stability studies were focused on the composite resin material in form of adhesive system or conventional restoration (Falkensammer et al., 2013; Jain et al., 2013; Kilinc et al., 2011; Miyagawa and Powers, 1983). There is lack of in vitro studies that evaluate the color stability for composite resin in form of veneer restoration whatever direct or indirect. The present study was aimed to evaluate the effect of the time and instant coffee on color stability of the prefabricated composite resin veneers and compare it with laboratory-made composite resin veneer. The null hypothesis of the present study was that there would be no significant difference between the color changes of the prefabricated veneer and laboratory-made veneer systems over time.

Methods and materials

Two prefabricated and one laboratory-made veneers were used in the present study as shown in Table 1. Eight veneers from each group (n=8) were cleaned by ultrasonic water bath (Renfert SYMBRO, Germany) with plaster solvent chemical solution (Gypsolve, England) to remove any accretion or industrial smear layer. Then, all samples were dried with non-oily dry air and stored in three different containers named (EDL, CMP and NEX). Then all

Veneer system	Compositions	Manufacturer
Edelweiss (EDL)	The veneer filler ratio is 82% by weight and 65% by volume. The variation of inorganic filler particle is between 0.02 – 0.03 µm.	Edelweiss Dentistry, Austria
Componeer (CMP)	Methacrylate, silanized barium glass, hydrophobized amorphous silicic acid. Filler content by weight is 80% and by volume is 65%.	Coltène/Whaledent AG ™, Switzerland
Nexco (NEX)	Aromatic aliphatic UDMA & Aliphatic dimethacrylates, Highly dispersed silicon dioxide, Copolymer, Catalysts and stabilizers and Pigments.	Ivoclar Vivadent™, USA

Table 1: Veneer system materials

samples were immersed in distilled water for 24 hours under room temperature (27°C). By using Minolta spectrophotometer CM–(C 3500), the value of L*, a* and b* were measured based on CIE (Commission International de l'Eclairage) for each sample to be considered as baseline value (day 0). Then, they were transferred to three different containers consist of staining solution, instant coffee. One veneer from each group was stored in distilled water container. The value of L*, a* and b* were measured every three days interval for 27 days and this group was considered as a control group.

Staining solution preparation

The staining solution consisted of instant coffee which was prepared by adding approximately 48 mg of coffee to 250 ml of boiling water (Jain et al., 2013). The solution was divided into three different containers for three different veneer groups.

Color measurement

After calibration setup completed, three measurements of (L*, a* and b*) were done with the active point of the center of each specimen. The mean readings of each sample were recorded and were used for overall data analysis. The same procedures were repeated every 72 hours interval (three days) for 27 days. At each time of measurement, veneer sample was removed from the containers and washed with 10 stroke of soft toothbrush under running tap water. Then, it was dried with soft doubled paper wipes. The coordinate value of each sample was re-measured with the same sequence of calibration and measurement. All coordinates (L*, a* and b*) values were collected manually and recorded. The color difference (ΔE*) between the color coordinates was calculated by applying the specific mathematical equation: $\Delta E^*=[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{½}$, in order to compare values before and after the storage treatment. ΔE* represent the color differences, ΔL* represent change in lightness, Δa* represent red-green coordinate and Δb* represent yellow-blue coordinate.

Data Collection and Statistical Analysis

All data were collected and recorded by manual and digital recording. The results were tabulate and subject to statistical analysis (IBM SPSS statistics v. 18 and W. Statistical Pro. by Evan Miller v. 1.8.8). Kolmogorov-Smirnov test was used to estimate the uniformity of the raw data distribution. For comparison between different variables, One-way ANOVA test and Student's t - test were used to compare between three different veneer groups.

Results

Table 2 shows the average mean values of (ΔE) for the three tested groups. The (ΔE) of EDL veneer group shows the highest mean values 10.07 ± 5.15 as compared to the other two veneer groups (CMP group mean values was from 7.41 ± 4.64 and NEX veneer group mean was 0.73 ± 0.5). While, (ΔE) of NEX ve-

Groups	Average (ΔE)	Minimum (ΔE)	Maximum (ΔE)
EDL	10.07 ± 5.15	9.83 ± 2.9	11.91 ± 3.1
CMP	7.41 ± 4.64	6.98 ± 2.5	9.19 ± 4.4
NEX	0.73 ± 0.5	0.68 ± 0.2	0.98 ± 0.3

Table 2: The (ΔE) mean and standard deviation values for the tested veneer groups.

neer group shows the lowest mean values. Figures 1 and 2 shows the liner correlation of the mean values of the color changes (ΔE) for all veneer groups through the experimental time intervals. In these two figures, the EDL veneer groups showed a significant change in the color ranged from 0 – 9.83 ± 2.9 in the first three days from storage in instant coffee solution. Then, in the next three days (day 6) showed slight color change (10.26 ± 2.9). After that, EDL veneer color change become more stable and ranged from 11.25 ± 3.3 to 11.91 ± 3.1 in the remaining 21 days of the experiments.

On the other hand, the CMP veneer group showed a significant change in the color ranged from 0 – 7.68 ± 3.2 in the first three days of experiments. After that, the CMP veneers become more color stable and ranged from 7.68 ± 3.2 to 9.19 ± 4.4 in the last 24 days of the experiments. Furthermore, the NEX veneers also showed significant color changes (p= 0.025) when compared with control group (distilled water) but showed lowest color changes when compared with EDL and CMP through experiment duration as shown in Figure 2a, 2b and 2c.

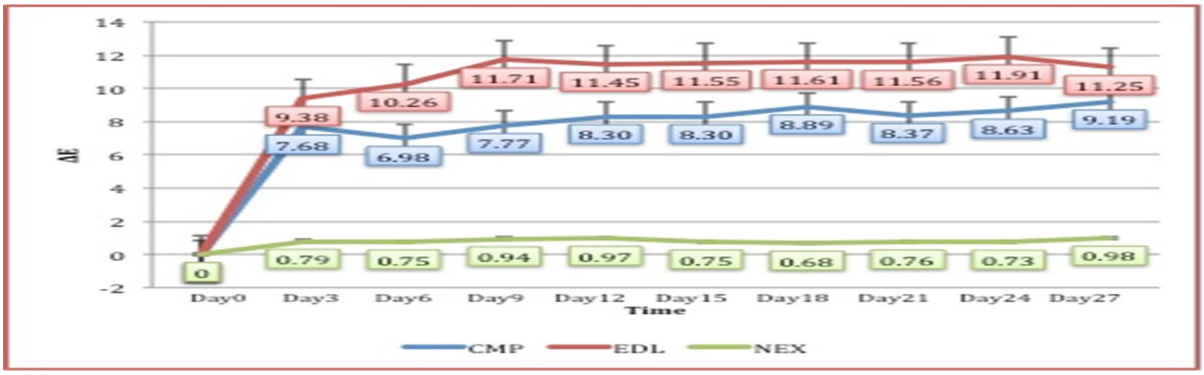


Figure 1: Liner correlation of the (ΔE) mean values of the veneer groups through time intervals.

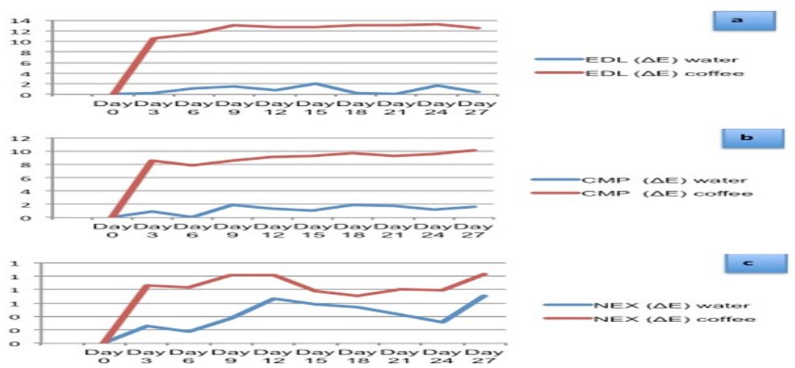


Figure 2: Liner correlation of the (ΔE) mean values of the veneer groups between instant coffee and distilled water media through time intervals.

Kolmogorov-Smirnov test was showed non-uniformly distributed values for surface roughness with 95% confidence intervals (α =0.05) as in Table 3. One-way ANOVA test was showed significant differences between average mean values of (ΔE) for the three veneer groups (P< 0.001) as in Table 4. While, Student's t-test reveled significant differences between mean values of (ΔE) within veneer groups as in Table 5.

Test Statistic D	Critical Value @5 % C	St. Error	Significant D>C	P-value
0.335	0.083	0.3	**Yes**	.000

Table 3: Kolmogorov-Smirnov test for the equality of distribution of the (ΔE) values. Color Stability (ΔE) departs from a uniform distribution (α =0.05).

Test Statistic F	Critical Value @5 % C	St. Error	Significant F>C	P-value
128.974	3.03	0.3	**Yes**	.000

Table 4: One-way ANOVA test for (ΔE) of the veneer groups. Average (ΔE) varies across values of Veneer (α =0.05).

		Test Statistic t	Critical Value @5 % C	St. Error	Significant t>C	P-value
CMP	EDL	3.634	1.973	0.4	**Yes**	.000
	NEX	13.562	1.973	0.3	**Yes**	.000
EDL	CMP	3.634	1.973	0.4	**Yes**	.000
	NEX	17.085	1.973	0.4	**Yes**	.000
NEX	CMP	13.562	1.973	0.3	**Yes**	.000
	EDL	17.085	1.973	0.4	**Yes**	.000

Table 5: Student's t- test for (ΔE) values within veneer groups.

Discussion

In principle, the composite resin veneers are widely used nowadays for different purpose regarding enhance the teeth shape, teeth alignment, cover discolored teeth and for smile design (Christensen, 2004; Dietschi and Devigus, 2011). However, one of the disadvantages is the color stability that it affects aesthetic and longevity of the restoration (Ertas et al., 2006; Jain et al., 2013). The null hypothesis of the present study was rejected: the results of one-way ANOVA test proved a significant difference between the amounts of color changes (ΔE) in the three veneer systems. Both of the prefabricated veneer systems showed significantly higher (ΔE) than laboratory-made veneer.

The EDL and CMP veneer groups showed significant increase in the ΔE in the first three days of immersing in the staining solution. As compared with the total amount of ΔE during the experiment, the first three days interval was the highest ΔE. After the first three days interval, both of EDL and CMP veneer groups showed relatively stable color changes until end of the tenth intervals. While, the NEX veneer group was showed significant and stable increase in the ΔE that ranged between 0.68 - 0.98 through the experimental duration. Jain et al. (2013) and Ertas et al. (2006) found that the composite resin material showed significant color changes when immersed in coffee solution. This is in agreement with the findings of the present study.

The ΔE value has many clinical implementations, as any ΔE below 3.3 consider clinically accepted (Jain et al., 2013) while the ΔE value of more than 5.5 considered exceeded the critical threshold (Falkensammer et al., 2013). The present study findings of the ΔE showed noticeable color changes in the prefabricated veneer systems and exceeding the critical threshold while the ΔE of the laboratory-made veneer system was clinically accepted. These findings could be attributed to many factors related to the color stability of the composite resin such as the composition of the resin matrix and the curing mechanism of the material (Kim and Lee, 2008).

Several studies showed that curing under nitrogen pressure at specific temperature and time will improve the color stability of the composite resin (Jain et al., 2013; Kim and Lee, 2008). Furthermore, another studies were showed that insufficient matrix monomer conversion within the composite will induces absorption for the staining substances (Jain et al., 2013; Stober et al., 2001). The details that related to curing methods and the manufacturing technologies for the two prefabricated veneer systems of the present study were never published or mentioned in the official website of the manufacturer companies.

The findings of the present study showed high tendency for the prefabricated veneer shell to change its color when exposure to instant coffee in the first three days. However, the prefabricated veneer system consist bonding and luting agents beside the veneer shell. All veneer system components have different color stability towards the staining solutions (Archegas et al., 2011; Kilinc et al., 2011). Based on that, the present study findings should be combined with other in vitro and in vivo studies related to color stability on prefabricated veneer systems to be more clinically significant.

The ΔE was measured with a standard quantifying device (Color Spectrophotometer, Minolta, USA) rather than visual examination for accuracy, reproducible and statistically utilizable results. The veneer samples were stored in distilled water before the experimental steps because of the difficulty to adapt the oral environmental variations of the human subjects (Kilinc et al., 2011).

The spectrophotometer device can operate with two different measuring geometrics: specular component included (SCI) and specular component excluded (SCE). In the present study, the SCE was used in measurements record as it was proved that the color changes measured with SCE geometry were greater than those measured with SCI geometry (Jain et al., 2013; Lee and Powers, 2007). The veneer samples thicknesses in the present study were within 1.0 mm to match the spectrophotometer requirements and the ISO standards for the sample thickness (< or = 2.24 mm) for reliable results (Kilinc et al., 2011; Miyagawa and Powers, 1983). The immersion duration for the veneer samples in the staining solution was set at four weeks as study done by Jain et al. (2013) and Bayindir et al. (2012).

Most of the color stability studies used different staining solutions for the ΔE evaluations such as instant coffee, nails varnish and wine (Falkensammer et al., 2013). In the present study, the instant coffee was used to evaluate the ΔE as considered one of the most common daily drink and have the highest effect on the color stability of the composite resin (Domingos et al., 2011; Jain et al., 2013; Organization, 2016).

Conclusions

Within the limitation of the present study, the laboratory-made veneer showed clinically accepted color stability when immersed in instant coffee solution. Both of the prefabricated composite resin veneers were showed noticeable color changes when immersed in instant coffee solution which were exceeded the critical threshold and not accepted clinically. The highest level of color changes amount for the EDL and CMP were presented in the first three days of the total experimental duration. After that, both prefabricated veneer systems were showed the same color stability behavior.

Acknowledgment

The present study was supported by the research fund from Faculty of Dentistry of University Tecknologi MARA and all the experimental devices were used from the Research laboratory of the faculty; therefore, the authors are thankful for that.

References

1. Archegas, L. R. P., Freire, A., Vieira, S., Caldas, D. B. d. M., & Souza, E. M. (2011). Colour stability and opacity of resin cements and flowable composites for ceramic veneer luting after accelerated ageing. ***J. of Dentistry.*** **39(11)**, 804-810.
2. Asmussen, E. (1981). An accelerated test for color stability of restorative resins. ***Acta Odontologica Scandinavica.*** **39(6)**, 329-332.
3. Bayindir, F., Kürklü, D., & Yanikoğlu, N. D. (2012). The effect of staining solutions on the color stability of provisional prosthodontic materials. ***J. of Dentistry.*** **40**, e41-e46.
4. Christensen. (2003). Direct restorative materials: What goes where? ***The J. of the American Dental Association.*** **134(10)**, 1395.
5. Christensen. (2004). What is a veneer. ***JADA.*** **135(11)**, 1574-1576.
6. Coltene/Whaledent. (2013). ***Retrieved June, 2013,*** from http://us.componeer.info/
7. Dietschi, D., & Devigus, A. (2011). Prefabricated composite veneers: historical perspectives, indications and clinical application. ***European J. of Esthetic Dentistry.*** **6(2)**.
8. Domingos, P. A. d. S., Garcia, P. P. N. S., Oliveira, A. L. B. M. d., & Palma-Dibb, R. G. (2011). Composite resin color stability: influence of light sources and immersion media. ***J. of Applied Oral Science.*** **19(3),** 204-211.
9. Ertas, E., Gueler, A. U., Yuecel, A. C., Koepruelue, H., & Gueler, E. (2006). Color stability of resin composites after immersion in different drinks. ***Dental materials journal.*** **25(2),** 371-376.
10. Falkensammer, F., Arnetzl, G. V., Wildburger, A., & Freudenthaler, J. (2013). Color stability of different composite resin materials. ***J. of Prosthetic Dentistry.*** **109(6),** 378-383.
11. Jain, V., Platt, J. A., Moore, K., Spohr, A. M., & Borges, G. A. (2013). Color stability, gloss, and surface roughness of indirect composite resins. ***J. of Oral Science.*** **55(1).**
12. Kilinc, E., Antonson, S. A., Hardigan, P. C., & Kesercioglu, A. (2011). Resin cement color stability and its influence on the final shade of all-ceramics. ***J. of Dentistry.*** **39,** e30-e36.
13. Kim, S.-H., & Lee, Y.-K. (2008). Changes in color and color coordinates of an indirect resin composite during curing cycle. ***J. of Dentistry.*** **36(5),** 337-342.
14. Le Roux, A. R., & Lachman, N. (2007). Dental composite materials: highlighting the problem of wear for posterior restorations. ***Durban University of Technology research publication*****. 89.**
15. Lee, Y.-K., & Powers, J. M. (2007). Color changes of resin composites in the reflectance and transmittance modes. ***Dental Materials.*** **23(3),** 259-264.
16. Miyagawa, Y., & Powers, J. (1983). Prediction of color of an esthetic restorative material. ***J Dent Res.*** **62(5),** 581-584.
17. Mosby. (Ed.) (2011) ***Mosby's Dental Dictionary (Vols. 2e).*** India: Elsevier Inc.
18. Organization, I. C. (2016). ***World Coffee Cocsumption Retrieved Nov 2016,*** 2016, from http://www.ico.org/about_statistics.asp?section=Statistics
19. Rosenstiel, S. F., Land, M. F., & Crispin, B.

J. (1998). Dental luting agents: a review of the current literature. ***J. of Prosthetic Dentistry.*** **80(3),** 280-301.

20. Schmidt, C. J., & Tatum, S. A. (2006). Cosmetic dentistry. ***Current opinion in otolaryngology & head and neck surgery.*** **14(4),** 254-259.
21. Stober, T., Gilde, H., & Lenz, P. (2001). Color stability of highly filled composite resin materials for facings. ***Dental Materials.*** **17(1),** 87-94.
22. Toh, C., Setcos, J., & Weinstein, A. (1987). Indirect dental laminate veneers—an overview. ***J. of Dentistry.*** **15(3),** 117-124.
23. Turkun, L. Ş., & Turkun, M. (2004). Effect of bleaching and repolishing procedures on coffee and tea stain removal from three anterior composite veneering materials. ***J. of Esthetic and Restorative Dentistry.*** **16 (5),** 290-301.
24. Ultradent. (2012). ***Retrieved June, 2013,*** from http://www.edelweiss-dentistry.com/en
25. Um, C. M., & Ruyter, I. (1991). Staining of resin-based veneering materials with coffee and tea. ***Quintessence International.*** **22(5).**
26. Vichi, A., Ferrari, M., & Davidson, C. L. (2004). Color and opacity variations in three different resin-based composite products after water aging. ***Dental Materials.*** **20(6),** 530-534.