©Operative Dentistry, 2015, **40-1,** E21-E27

Efficacy of Do-It-Yourself Whitening as Compared to Conventional Tooth Whitening Modalities: An In Vitro Study

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Clinical Relevance

Professionally applied in-office whitening, professionally dispensed patient-applied home whitening, and the use of an over-the-counter product are effective in changing tooth color toward a lighter shade, whereas do-it-yourself whitening is not an effective tooth whitening modality.

SUMMARY

Aim: To evaluate the efficacy of do-it-yourself (DIY) whitening as compared to conventional tooth whitening modalities using different shade assessment tools.

Methods and Materials: Extracted human molars (120) were randomly distributed to six groups (n=20). Whitening was performed according to manufacturer's directions for over-the-counter, dentist-dispensed for home use, and in-office whitening. DIY whitening consisted of a strawberry and baking soda mix. Additionally, negative and positive controls were used. Two evaluators used the Vita Classical (VC) and Vita Bleachedguide 3D-Master with interpolated numbers (BGi) for visual assessment at baseline and one-week, one-month, and three-month postwhitening. Instrumental measurements were performed with a spectrophotometer. Kruskal-Wallis procedure was used to assess color changes among groups and intraclass correlation (ICC) to evaluate agreement between evaluators.

Results: DIY exhibited lower color change (ΔSGU_{VC}, ΔSGU_{BGi}, ΔE^*, where SGU = shade guide unit and E = overall color change) compared to other whitening groups at all time points ($p<0.05$). ICC demonstrated very

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DOI: 10.2341/13-333-LR

good agreement between evaluators with VC and BGi at each time point. Both shade guides were related with each other and strongly related to instrumental measurements ($p<0.05$).

Conclusions: DIY whitening was the least effective whitening modality. Both VC and BGi are related with each other and have good correlation with instrumental measurements.

INTRODUCTION

Demand for tooth whitening has been building and growing for more than a decade as people envision and desire a "Hollywood smile." Tooth whitening now represents the most common elective dental procedure[1] and has proven to be safe and effective when supervised by a dentist.[2] More than 1 million Americans whiten their teeth annually, driving nearly $600 million in revenues for dental offices.[1] The high demand is also reflected by the wide range of whitening modalities available: professionally applied in-office whitening; professionally dispensed patient-applied home whitening, and over-the-counter (OTC) products.[2]

The penchant to do it yourself has swept through myriad websites promoting the use of at-home whitening remedies,[3] including rubbing crushed strawberries or apples on the teeth. Thus, a new category has emerged that can be described as do-it-yourself (DIY) whitening using natural ingredients.[4] The advocated use of fruits such as strawberries and apples is based solely on anecdotal evidence with the rationale that they contain malic acid. Considering the current evidence of the erosion potential of fruit-containing beverages and smoothies[5-8] and controversies on the safety of DIY methods,[9] appropriate cautions for their use in tooth whitening is paramount.

Tooth whitening efficacy has been evaluated visually with clinically accepted shade guides and instrumentally with electronic color measuring devices. The Vita Classical (VC; Vita Zahnfabrik, Bad Säckingen, Germany) developed in 1956 is one of the most commonly used shade guides. However, its use in monitoring tooth whitening has been disputed due to a lack of logical order, uniform color distribution, and light shade tabs, thus limiting the design of whitening studies.[10] The Vita Bleached-guide 3D-Master (BG; Vita Zahnfabrik) was introduced in 2007 to increase the reliability and validity of visual color assessments by including more whitening shade tabs, uniform distribution between the tabs, and a visually perceivable light to dark value order.[11] The BG tabs are now available with new markings, with each tab marked with odd numbers from 1 to 29 and with "interpolated" even numbers in between. The main advantage of the interpolated BG (BGi) that has been reported is that the distribution of the tabs better corresponds to the American Dental Association (ADA) equation that 1 ccu = 1 SGU = 1 ΔE^* (ccu = color change unit; SGU shade guide unit; ΔE^* = overall color change).[12]

With heightened consumer interest in whiter teeth, it is the responsibility of the dental profession to educate the patient and the public about the efficacy and adverse effects of different tooth whitening modalities, suggest or provide appropriate whitening options based on patient's needs and preference, and establish reliable and valid monitoring tools for the whitening process. According to the current literature, there seems to be a lack in knowledge of comparing whitening efficacy of all four whitening modalities. There is also a lack of information on the correlation of the newly introduced interpolated shade guide with conventional shade guides.

The purpose of this study was to compare the efficacy of DIY whitening as compared to conventional whitening modalities with respect to tooth color change. Tooth color change was monitored with three different shade evaluation methods: visual assessment using VC and Interpolated BGi and spectrophotometric color assessment with the Vita Easyshade Compact (ES; Vita Zahnfabrik).

The null hypotheses to be tested were the following. First, there will be no difference in tooth color change among the four different whitening modalities. Second, there will be no differences in agreement between the two evaluators using VC and BGi. Third, there will be no correlation between visual and instrumental color measurements.

METHODS AND MATERIALS

Sample Selection and Preparation

Extracted sound human third molars without identifiers (120) were collected and stored in 0.2% sodium azide solution at 4°C. Teeth were cleaned of gross debris and placed in artificial saliva for 24 hours at 37°C prior to initiating the experiment. Artificial saliva was prepared and replaced daily according to the modified Fusayama solution as described in ANSI/ADA Specification 41.[13]

Table 1: *Active Ingredient, pH, and Application Regimen by Group*

Group	Concentration	pH	Application Regimen
NC: water of grade 3		7.0	One application (60 min), at 35°C
DIY: strawberry mix	CA	7.2	Three applications (5 min each) at 5-d intervals
OTC: Crest 3D Intensive	9.5% HP	6.0	One daily application (2 h) for 7 d
HW: Opalescence PF	10% CP	7.4	One daily application (6 h) for 14 d
OW: Zoom WhiteSpeed	25% HP	7.2	Three applications (45 min each) at 5-d intervals
PC: citric acid	1.0% CA	3.9	One application (60 min), at 35°C

Abbreviations: CA, citric acid; CP, carbamide peroxide; DIY, do-it-yourself; HP, hydrogen peroxide, HW, home whitening; NC, negative control; OTC, over-the-counter; OW, office whitening; PC, positive control.

Experimental Groups

Specimens were randomly distributed into six groups of 20 specimens each and mounted on acrylic molds to expose the crown portion for the different whitening treatments. The active ingredient, pH, and application regimen by group are summarized in Table 1. The treatment regimen for each group followed manufacturers' instructions or recommendations for typical use. DIY represented a method using a puree of strawberry (15 g) mixed with baking soda (2.5 g; Arm & Hammer Baking Soda, Church & Dwight Co, Inc, Princeton, NJ, USA) for five minutes followed by brushing with a soft toothbrush (Colgate Oral Pharmaceuticals, Inc, New York, NY, USA) for 30 seconds. The procedure was repeated two more times at five-day intervals. Group OTC received daily applications of whitening strips for two hours (Crest 3D Intensive, Crest Pro Health, Procter & Gamble, Cincinnati, OH, USA) for seven days. Group HW was treated with a 10% carbamide peroxide gel (Opalescence PF, Ultradent Products Inc, South Jordan, UT, USA) placed in a custom fabricated tray for six hours for 14 days (0.12 ml/tooth). Group OW represented the professionally applied group treated with 25% hydrogen peroxide (Philips Zoom White Speed, Philips Oral Healthcare, Los Angeles, CA, USA) with three applications for 45 minutes using light activation. The whitening material was replenished every 15 minutes according to the manufacturer's instructions. The negative (NC) and positive control (PC) groups were treated according to the International Organization for Standardization (ISO) 28399 protocol with grade 3 water and 1.0% citric acid for 60 minutes at 35°C, respectively.[14]

Tooth Color Change Assessment

Two shade guides, the VC and BGi, were used for visual color assessment (Figures 1 and 2). Measurements were performed under a color-controlled light box (MM 4e GTI Mini Matcher, GTI Graphic Technology, Inc, Newburgh, NY, USA) at CIE D_{65}, a color temperature of 6500 K, and light intensity of ≈1200 lux by two evaluators with superior color matching competency (ISO/TR 28642).[15] Results were expressed in difference of shade guide units (ΔSGU) for the respective shade guides. Instrumental color measurements were performed on the middle third of the buccal surface using a contact-type intraoral spectrophotometer (ES), Vita Easyshade Compact, with the use of a custom-fabricated clear jig for repeatable measurements (Figure 3). The overall color change as measured with the

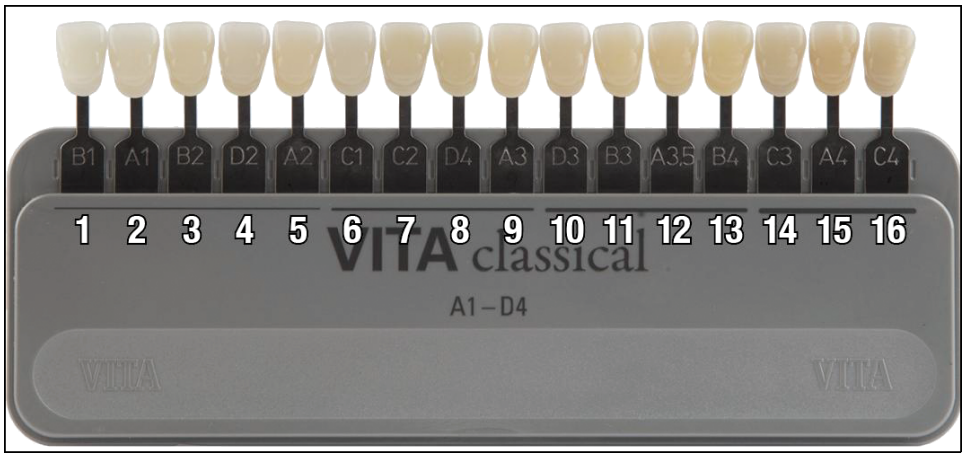

Figure 1. *Value-oriented Vita Classical Shade Guide.*

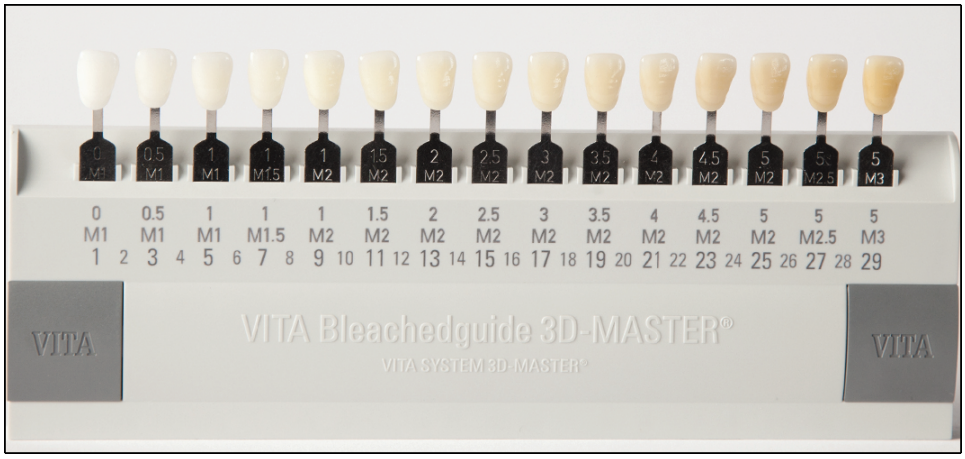

Figure 2. *Vita Bleachedguide 3D-Master with interpolated numbers.*

spectrophotometer was expressed as ΔE* from the Commission Internationale de l'Eclairage. The following equation was used:

$$\Delta E* = [(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2]^{1/2}$$

The color differences were calculated relative to baseline color parameters (L^*_1, a^*_1, b^*_1). Measurements were performed with the VC, BGi, and ES at baseline (T_1), one-week postwhitening (T_2) and one-month (T_3), and three-month postwhitening (T_4).

Statistical Analysis

Measurements of color change included ΔSGU_{VC}, ΔSGU_{BGi}, and ΔE*. The Kruskal-Wallis procedure was used to determine significant differences in color change among the groups. Friedman's test was used to evaluate differences in color change across the different time points. Intraclass correlation (ICC) was used to assess the agreement between the two evaluators using the VC and BGi. Correlations between visual and instrumental measurements were assessed with Pearson correlations. Tests of hypotheses were two sided with an alpha level of 0.05. Analysis was conducted with SAS version 9.2 (SAS Institute, Cary, NC, USA).

RESULTS

Visual and instrumental color changes by groups at three time points are summarized in Table 2. Baseline color parameters of the six groups were not different with the visual and the instrumental methods ($p>0.05$). However, color changes among the groups were significantly different at all time periods for the visual and instrumental methods ($p<0.05$). Post hoc tests (Scheffe) for VC, BGi, and ES at one week (T2-T1), one month (T3-T1), and three months (T4-T1) showed that there were significantly greater color changes in groups OTC, HW, and OW than in groups NC, DIY, and PC. ($p<0.05$). At three months, the greatest overall color change (ΔE*) was observed for group OW ($p<0.05$; Figure 4). However, visual assessment showed no difference among OTC, HW, and OW at three-month

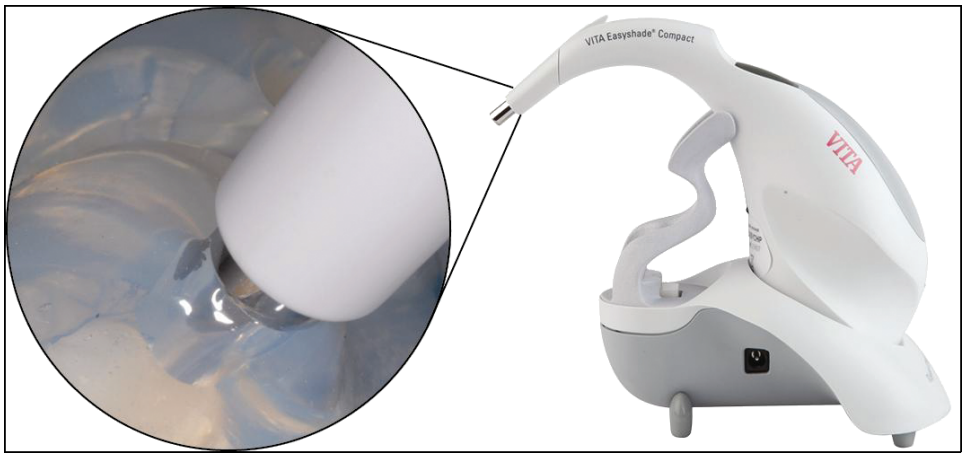

Figure 3. *Vita Easyshade Compact and the use of custom-fabricated clear jigs for repeated measurements.*

Table 2: *Visual and Instrumental Color Changes (Mean [SD]) by Groups at Three Time Points*[a]

Group	1 wk (T2-T1)			1 mt (T3-T1)			3 mt (T4-T1)		
	ΔSGU_{VC}	ΔSGU_{BGi}	ΔE^*	ΔSGU_{VC}	ΔSGU_{BGi}	ΔE^*	ΔSGU_{VC}	ΔSGU_{BGi}	ΔE^*
NC	0.4(0.8) A	−0.6 (1.5) AC	3.2 (2.0) A	1.3 (1.4) A	0.7 (1.8) A	2.2 (1.5) AC	1.4 (1.3) A	0.1 (1.5) A	2.3 (1.0) A
DIY	0.5 (1.1) A	1.0 (1.2) A	4.0 (1.9) A	−0.1 (1.8) AC	−1.1 (1.4) A	4.9 (1.9) AD	−0.1 (1.3) A	1.0 (2.3) A	2.4 (1.4) A
OTC	7.4 (2.4) B	11.0 (2.2) B	10.0 (2.6) C	8.1 (2.0) B	11.5 (2.5) B	14.6 (2.8) B	8.6 (2.3) B	12.0 (2.1) B	14.0 (3.0) B
HW	7.7 (3.0) B	11.6 (2.3) B	13.8 (2.4) D	7.7 (3.0) B	11.4 (2.4) B	15.7 (2.8) B	7.5 (3.0) B	12.0 (2.0) B	15.3 (2.4) B
OW	7.7 (1.9) B	12.7 (2.0) B	17.3 (3.3) E	8.0 (2.0) B	13.5 (1.9) B	18.1 (3.4) B	8.0 (2.0) B	13.6 (2.1) B	17.6 (2.8) C
PC	1.1 (1.2) A	1.6 (2.5) AD	5.1 (2.4) A	2.0 (1.4) AD	1.7 (1.9) A	4.6 (2.1) A	1.4 (1.8) A	1.4 (2.0) A	2.53 (1.0) A

Abbreviations: DIY, do-it-yourself; HW, home whitening; NC, negative control; OTC, over-the-counter; OW; office whitening; PC, positive control.
[a] *Within columns, different letters indicate means that are statistically different ($p<0.05$).*

evaluation ($p>0.05$). At three months, NC, DIY, and PC showed an overall color change of 2.3, 2.4, and 2.53, respectively, which is less than the perceptibility threshold of ΔE 2.6 units.[16]

The levels of ICC demonstrated high agreement between the two evaluators using both the VC and the BGi. It is noteworthy that the agreement at baseline (T1) was significantly lower than the agreement observed at T2-T4 for both BGi and VC (Table 3). Assuming linear correlation, the shade guides were strongly and positively related with each other. Both shade guides were strongly related with the instrumental measurements (Table 4).

DISCUSSION

This is the first study that compared the efficacy of a DIY whitening regimen as compared to three conventional whitening modalities. The result of this study is partially limited by the use of extracted human teeth, which will inherently differ from vital teeth in the oral environment. Based on the results, the first null hypothesis was rejected, as significant differences in color change were detected among the four whitening modalities. The second hypothesis was retained; there was no significant difference in agreement between the two evaluators when comparing both shade guides. The data support the rejection of the third hypothesis because of strong correlations between the shade guides and the instrumental measurements.

Several studies have compared the efficacy of OTC products, home whitening, and in-office whitening.[17-19] According to a clinical study that compared three different whitening techniques with respect to the whitening times required to achieve a defined level of whitening, the cycles required increased from office whitening to home whitening to OTC products. That is, one in-office session was comparable to approximately seven days of home whitening and 16 days of using an OTC product.[18] Another clinical study found that home whitening and in-office whitening were superior to OTC whitening

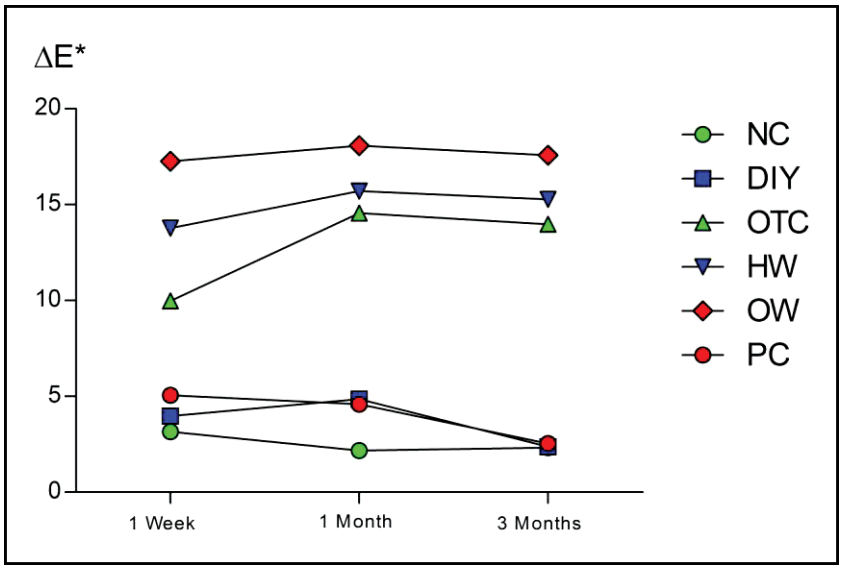

Figure 4. *Overall color change (ΔE*) by group at different time points.*

Table 3: *Agreement Between the Two Evaluators Using VC and BGi*

Shade Guide	Time	ICC	Confidence Interval	
			Lower Bound	Upper Bound
VC	Baseline (T1)	0.777	0.674	0.847
	1 wk (T2)	0.924	0.889	0.948
	1 mo (T3)	0.95	0.868	0.975
	3 mo (T4)	0.954	0.93	0.969
BGi	Baseline (T1)	0.86	0.645	0.93
	1 wk (T2)	0.966	0.946	0.977
	1 mo (T3)	0.984	0.975	0.989
	3 mo (T4)	0.982	0.973	0.988

Abbreviation: ICC, intraclass correlation.

products when followed for up to three months.[19] Our study results showed that the whitening efficacy of Crest Whitestrips, an OTC product, was comparable to professionally dispensed home whitening and professionally applied in-office whitening for up to three months postwhitening when evaluated visually with shade guides. The varying results compared to previous studies may be explained by the difference in study design (e.g., *in vivo* vs *in vitro*) and the difference in whitening products employed. It is important to point out that the change from original Whitestrips using a polymer-based hydrogel system to the new advanced seal technology with an improved seal and increased hydrogen peroxide concentrations may have affected the study results.[20]

DIY whitening with strawberries as well as the positive control group using 1.0% citric acid was not effective in whitening, which showed that color change is not due to the acid component in fruits.

Agreement between the two evaluators was very good for both shade guides VC and the BGi. This is contrary to a study that showed superior performance assessment with the Linearguide 3D-Master compared to the Vita Classical.[21] This can be partly explained by the limitation of the lack of lighter shade tabs in the VC. After specimens were bleached, the only choice was the B1 tab, resulting in high agreement between the two evaluators using the VC. Thus, it is noteworthy to point out that ICC was higher for BGi than VC at all time points, although it was not statistically significant.

Table 4: *Correlations Between Visual and Instrumental Measurements*

	VC	BGi	ΔE*
VC			
Pearson correlation	1	0.896**	0.828**
p-value		0	0
BGi			
Pearson correlation	0.896**	1	0.890**
p-value	0		0
ΔE*			
Pearson correlation	0.828**	0.890**	1
p-value	0	0	

*** Correlation is significant at the 0.01 level, N=360 in all instances.*

The results of this study demonstrated a good correlation between the two shade guides and the instrumental measurements. This supports the use of both shade guides as acceptable tooth shade guides and the use of electronic color measuring instruments for laboratory assessment of tooth whitening efficacy, as described in ADA acceptance guidelines and ISO Standards.[14,22,23] It also suggests that, whenever possible, both visual and instrumental methods should be used, as they complement each other.[24]

Within the limitations of the study, the data provided important information about the efficacy of different whitening modalities. This will provide a resource to recommend and educate the public about the most effective tooth whitening modality. Future studies on the adverse effects of different whitening modalities should be performed to address the effect on surface roughness, microhardness, and surface morphology. Thus, any abuse of tooth whitening that may lead to moderate to severe loss of tooth structure may be prevented.

CONCLUSIONS

DIY whitening with the use of a strawberry mixture is not an effective tooth whitening modality when compared to professionally applied in-office whitening, professionally dispensed patient-applied home whitening, and an OTC product. Both shade guides VC and BGi are related with each other and have good correlation with instrumental measurements.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 26 May 2014)

REFERENCES

1. Dutra A, Frary J, & Wise R (2004) Higher-order needs drive new growth in mature consumer markets *Journal of Business Strategy* **25(5)** 26-34.

2. American Dental Association Council on Scientific Affairs (2009) *Tooth Whitening/Bleaching: Treatment Considerations for Dentists and Their Patients* American Dental Association, Chicago.
3. Natural teeth whitening solutions; Retrieved online May 8, 2014 from: http://www.doctoroz.com/videos/natural-teeth-whitening-solutions
4. Kwon SR, & Li Y (2013) Ensure the success of tooth whitening: How to effectively monitor color change during the bleaching process *Dimensions of Dental Hygiene* **11(5)** 52-55.
5. Hemingway CA, Parker DM, Addy M, & Barbour ME (2006) Erosion of enamel by non-carbonated soft drinks with and without toothbrushing abrasion *British Dental Journal* **201(7)** 447-450.
6. Blacker SM, & Chadwick RG (2013) An in vitro investigation of the erosive potential of smoothies *British Dental Journal* **214(4)** E8.
7. Ali H, & Tahmassebi JF (2014) The effects of smoothies on enamel erosion: an in situ study *International Journal of Paediatric Dentistry* **24(3)**184-191.
8. Sari ME, Erturk AG, Koyuturk AE, & Bekdemir Y (2014) Evaluation of the effect of food and beverages on enamel and restorative materials by SEM and Fourier transform infrared spectroscopy *Microscopy Research and Technique* **77(1)** 79-90.
9. Hammel S (1998) Do-it-yourself tooth whitening is risky *US News and World Report* April 2 p 66.
10. Paravina RD (2008) New shade guide for tooth whitening monitoring: Visual assessment. *Journal of Prosthetic Dentistry* **99(3)** 178-184.
11. Ontiveros JC, & Paravina RD (2009) Color change of vital teeth exposed to bleaching performed with and without supplementary light *Journal of Dentistry* **37(11)** 840-847.
12. Ontiveros JC, Eldiwany SM, & Paravina RD (2012) Clinical effectiveness and sensitivity with overnight use of 22% carbamide peroxide gel *Journal of Dentistry* **40s(12)** e17-e24.
13. American Dental Association (2005) ANSI/ADA Specification No. 41 for Recommended Standard Practices for Biological Evaluation of Dental Materials *Chicago: American Dental Association*.
14. International Organization for Standardization (2011) ISO 28399 Dentistry—Products for external tooth bleaching *Geneve: International Organization for Standardization*.
15. International Organization for Standardization (2011) ISO/TR 28642 Dentistry—Guidance on color measurement *Geneve: International Organization for Standardization*.
16. Douglas RD, Steinhauer TJ, & Wee AG (2007) Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade match *Journal of Prosthetic Dentistry* **97(4)** 200-208.
17. Da Costa JB, McPharlin R, Paravina RD, & Ferracane JL (2010) Comparison of at-home and in-office tooth whitening using a novel shade guide. *Operative Dentistry* **35(4)** 381-388.
18. Auschill TM, Hellwig E, Schmidale S, Sculean A, & Arweiler NB (2005) Efficacy, side-effects and patients' acceptance of different bleaching techniques (OTC, in-office, at-home) *Operative Dentistry* **30(2)** 156-163.
19. Bizhang M, Chun Y-HP, Damerau K, Singh P, Raab WH-M, & Zimmer S (2009) Comparative clinical study of the effectiveness of three different bleaching methods. *Operative Dentistry* **34(6)** 635-641.
20. Oliveira GM, Miguez PA, Oliveira GB, Swift EJ Jr, Farrell S, Anastasia MK, Conde E, & Walter R (2013) Safety and efficacy of a high-adhesion whitening strip under extended wear regimen *Journal of Dentistry* **41s(8)** e46-e52.
21. Paravina RD (2009) Performance assessment of dental shade guides *Journal of Dentistry* **37s(Supplement 1)** e15-e20.
22. American Dental Association Council on Scientific Affairs (2006) *Acceptance Program Guidelines: Dentist-Dispensed Home-Use Tooth Bleaching Products* American Dental Association, Chicago.
23. American Dental Association Council on Scientific Affairs (2006) *Acceptance Program Guidelines: Over the Counter Home-Use Tooth Bleaching Products* American Dental Association, Chicago.
24. Chu SJ, Trushkowsky RD, & Paravina RD (2010) Dental color matching instruments and systems. Review of clinical and research aspects *Journal of Dentistry* **38s(Supplement 2)** e2-e16.