European Journal of Orthodontics 23 (2001) 411–415

Enamel colour changes following whitening with 10 per cent carbamide peroxide: a comparison of orthodontically-bonded/debonded and untreated teeth

J. K. Hintz*, T. G. Bradley** and T. Eliades***

*Private Practice, Corlane, Idaho, **Division of Orthodontics, School of Dentistry, Marquette University, Milwaukee, Wisconsin, USA and ***Biomaterials Science Unit, Dental School, University of Manchester, UK

SUMMARY The purpose of this study was to determine if a colour difference exists between teeth that had orthodontic appliances bonded to and debonded from them and untreated controls subjected to whitening with 10 per cent carbamide peroxide. The sample consisted of 20 pairs of first and second premolars extracted for orthodontic reasons. The contralateral surfaces were divided into an experimental and control group. The experimental group underwent orthodontic bonding/debonding procedures. Both groups were subjected to 4 hour whitening and 20 hour hydration sessions for 30 days. The $L^*a^*b^*$ colour system was chosen to evaluate any colour change and these changes were calculated by determining the ΔE from the $L^*a^*b^*$ values using a colorimeter. Colour change readings were taken before and after each 4 hour whitening. Additional readings were taken at 48 hour intervals for 30 days following the cessation of active whitening. The results were analysed using statistical (ANOVA) and graphical analyses ($\alpha = 0.05$). A colour change difference of 2 CIELAB units was set as being clinically significant.

A mean clinical colour difference was found for enamel surfaces subjected to orthodontic bonding/debonding of attachments relative to control sites after whitening. Bonding and debonding procedures resulted in a significant colour difference between orthodontic bonded and control sites at the end of the active period, which became insignificant at the end of the 30 day period of monitoring. Both the control and debonded sites responded to whitening; however, the control sites responded initially to a greater extent; the orthodontic debonded sites did not respond until after 2 weeks of continuous whitening. After the 2 week period the improved response of the debonded sites decreased the colour difference between the two groups.

Introduction

Vital tooth whitening is a safe and well-accepted procedure for the treatment of surface and intrinsic staining of teeth (Matis *et al*., 1998). After the removal of orthodontic appliances a residual amount of adhesive usually remains on the surface (Kinch *et al*., 1989). Since resin tags extend a distance in the order of 30–50 μm into the enamel, some may be left intact even though a layer of enamel is removed (Zachrisson and Årtun, 1979) and this could obstruct the natural movement of bleaching/whitening agents. In addition excess resin is removed by a mechanical process, which can result in varying amounts of enamel being removed (Van Waes *et al*., 1997) affecting the reflectance of light.

Despite the relatively extensive evidence available on decalcification, the incidence of enamel colour changes associated with orthodontic bonding has not been investigated. A recent study showed that enamel colour variables were affected by enamel bonding and debonding procedures (Eliades *et al*., 2001). Enamel colour

alterations may derive from the irreversible penetration of resin tags into the enamel structure at depths reaching 50 μm (Silverstone *et al*., 1975). Since resin impregnation in the enamel structure cannot be reversed by debonding and cleaning procedures (Sandisson, 1981), enamel discolouration may occur by direct absorption of food colourants and products arising from the corrosion of the orthodontic appliance (Maijer and Smith, 1982).

The hypothesis tested in this research was that whitening may induce a clinically measurable colour difference in teeth subjected to orthodontic bonding and debonding procedures relative to untreated controls. Therefore the purpose of this study was to investigate the colorimetric parameters of enamel surfaces subjected to whitening with 10 per cent carbamide peroxide in untreated and orthodontically bonded/debonded teeth.

Materials and methods

The buccal surfaces of 16 pairs of first and second premolars extracted for orthodontic reasons were used for the study. Four pairs with lingual surfaces sufficiently large for testing when extracted were also included. Thus, a total of 40 enamel surfaces were included in the study. The teeth were prepared by first cleaning with a scaler and then polishing with fine pumice slurry (Hereus Kulzer, South Bend, IN, USA) using a slow handpiece equipped with a disposable prophylaxis head (Dentsply, York, PA, USA) because the manufacturer of the whitening system (Rembrandt Bleaching Gel, Den Mat, Santa Maria, CA, USA) recommends cleaning prior to bleaching. A positioning appliance and whitening tray were fabricated for each tooth using an indirect method. Each embedded crown surface was divided into equal halves using callipers and the midpoint of each tooth was calculated. Guide holes were drilled into the test surface midpoint at approximately the same angle for each pair. This facilitated the construction of a positioning appliance and a whitening tray for each tooth to allow repeatable measurements of the same test area. It also held the test surface at the same angle to the measuring head of the calorimeter during each measurement. A colorimeter (Minolta CR-321, Japan) was used to record colour variables L^*, a^*, b^* according to the CIE Lab (Commission Internationale de l' Eclairage, L^*, a^*, b^*) system. The CIE colour L^* parameter corresponds to the value or degree of lightness in the Munsell system, whereas the a^*, and b^* co-ordinates designate positions on red/green ($+a^*$ = red, $-a^*$ = green) and yellow/blue ($+b^*$ = yellow, $-b^*$ = blue) axes. The source light was provided by a pulsed xenon arc lamp to provide profuse even lighting over a 3 mm measuring area. The illuminate condition was set to D65 for testing, which best represents average daylight, including the ultraviolet region. Specimens were illuminated at an angle of 45 degrees to the surface permitting analysis of the light reflected perpendicular to the enamel surface. Each experimental specimen was placed into its positioning appliance and a commonly used bracket (MiniDiamond, 'A' Company/Ormco, Glendora, CA, USA) was bonded to the test surface area using a light-cured adhesive (Transbond XT, 3M/Unitek, Monrovia, CA, USA) exposed to a curing light (Ortholux XT, 3M/Unitek) according to the manufacturer's instructions. After a 24 hour storage period the brackets were debonded and the residual resin was removed with a 30-fluted bur (Brasseler 246LUF, CA, USA), using a light unilateral brush-stroke technique (Zachrisson and Årtun, 1979) followed by a 30 second fine pumice polish.

A 10 per cent carbamide peroxide solution was used as the whitening agent. The maximum whitening regime was chosen to cover all degrees of staining; 4 hours per day for 30 days. To control the effects of temperature and lighting, the samples were stored and whitened in black containers placed in a water bath of 37°C for the duration of the project. A pilot study had shown that a hydration period of at least 16 hours was needed to restore the colour variables of a dehydrated surface to the wet condition. Thus, for the purpose of this study, the surfaces were hydrated for 20 hours after whitening and a 10 second period was allowed for the specimen to be loaded into the positioning appliance and positioned on the measuring head. All

40 surfaces were whitened for 4 hours per day over a 30 day period. Measurements were taken before and immediately after each session for the duration of whitening on wet enamel specimens. Following completion of whitening sessions, measurements were recorded every 48 hours, starting at day 31 and ending on day 61. Measurements were taken until colour parameters of all teeth were shown to be steady in the last two 48 hour intervals. Colour parameters were averaged for each group and colour differences ΔE were calculated using the following equation (CIE, 1978):

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

which becomes more accurate with increasing ΔE (Seghi *et al*., 1989).

The results were analysed using graphical data and ANOVA statistical analysis at $\alpha = 0.05$ level of significance. The clinical colour difference level was set at 2 CIELab units.

Results

Figure 1 shows that differences can be identified between orthodontically treated and untreated enamel surfaces initially. For the majority of days during the active whitening period, a significant colour difference was present. However, for the 30 day monitoring period following discontinuation of active whitening, the clinical colour difference was not clinically significant with the exception of two days, since the lower 95 per cent confidence interval was below 2 CIELab units.

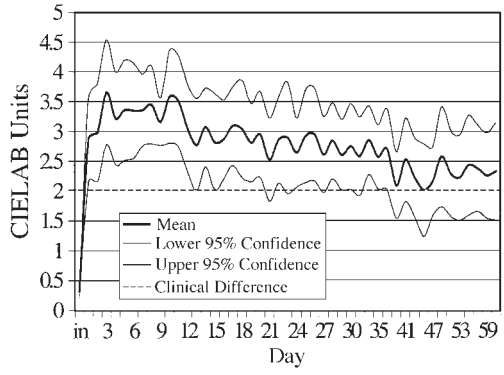

Figure 1 Variation of ΔE of the groups included in the study during the active whitening and the 30 day monitoring period.

Discussion

Generally, ΔE values less than 1 unit are considered as a colour match since they cannot be identified by independent observers (Seghi *et al*., 1989). It has been suggested that differences exceeding 2 units may indicate colour change (Wozniak, 1987), but some studies set the proposed acceptance limit for colour matching to 3.7 units, beyond which the differences are clinically visible (Johnston and Kao, 1989). Establishing low threshold values (CIELab units) contributes to increasing the sensitivity and soundness of the method, since the probability of missing clinically visible differences decreases.

Based on the fluctuation of the clinically-detectable colour difference derived from the threshold of 2 CIELab units, the specimen pairs included in the study could be separated into four groups. A number of pairs started with no difference at day 1 and remained this way at the end of testing. Pairs belonging to another group also started with no colour difference but developed a colour change at the end of testing. A third group consisted of pairs where there was a variation at the beginning but no clinical difference at the end. Lastly, in another group of teeth, the pairs started with a colour difference and also ended with a colour difference. These variations may reflect intrinsic variables of enamel structure related to the years of service intraorally or other unidentified parameters.

The results of this investigation show that a mean clinical difference between the test groups existed on the last day of testing (active whitening period). The mean colour difference was found to be above 2 CIELab units, but the significance of this difference was not determined since the lower confidence interval was slightly below 2 CIELab. An interesting finding was identified in individual ΔE graphs (not shown), where nine of the 20 pairs had colour differences that ranged between 2 and 8 CIELab units at the end of the active whitening period. Two

of the pairs (6 and 20) continued to present unusually large colour differences at day 61, which represents the end of the monitoring period.

There are three possible variables in the debonding procedure, which may be responsible for the differences seen on the experimental surfaces. The saturation of enamel by resin tags and the amount of residual adhesive may vary substantially for each test surface. This could lead to different degrees of colour reflectance as a result of the implication of the resin colour and the material left on the tooth surface. The debonding procedure may also alter the morphology of the enamel as reported by previous studies (Zachrisson and Årthun 1979; Kinch *et al.*, 1989). Changes in the morphological condition can affect the degree of light reflected from the test surface and analysed by the colorimeter. In addition, the amount of enamel lost by the debonding procedure (Van Waes *et al*., 1997) could be different for each surface resulting in colour difference not only between the individual experimental surfaces but also between the experimental and control surfaces.

The post whitening daily colour change graph shows that both test groups responded differently at each consecutive day following day 1 (Figure 1). The control group maintained its higher initial level of response through day 2 to day 12, but after this period the experimental group responded more rigorously, resulting in the difference between the two groups becoming smaller. For the daily colour changes recorded, the control group showed a significant clinical difference by day 2, while this did not occur until day 4 for the experimental group. The daily colour change response remained higher for the control group up to day 12, but shortly after this the experimental group had similar changes. These value separations indicate that the control and experimental surfaces responded differently to whitening. The lack of initial response by the experimental group supports the assumption of resin tags affecting the penetration of the whitening agent, or delaying the penetration into the enamel rod. Once a path of penetration is established, the ability of the whitening agent to remove stain from the enamel improves. This delayed response is reflected in the finding that no significant colour change was present between the treated and untreated groups at the end of the 30 day monitoring period.

The clinical relevance of the finding pertains to the potential need for modification of bleaching protocols on teeth previously subjected to orthodontic bonding and debonding. It must be noted, however, that *in vitro* tests may not reflect the clinical situation reliably and thus randomized clinical trials are necessary to further verify the findings of this study *in vivo*.

Address for correspondence

Dr T. Gerard Bradley
Department of Orthodontics
School of Dentistry
Marquette University
604 N. 16th Street
Milwaukee, WI 53201-1881, USA

Acknowledgement

The authors would like to thank the Minolta Corporation for the loan of the colorimeter used in this investigation.

References

Bureau central de la Commission Internationale de l'Eclairage (CIE) 1978 Recommendations on uniform colour-spaces, colour difference equations, psychometric colour terms. Paris, Supplement No. 2 to CIE publication No. 15: pp. 9–12

Eliades T, Kakaboura A, Eliades G, Bradley T G 2001 Comparison of enamel colour changes associated with orthodontic bonding using two different adhesives. European Journal of Orthodontics 23: 85–90

Johnston W M, Kao E C 1989 Assessment of appearance match by visual observation and clinical colorimetry. Journal of Dental Research 68: 819–822

Kinch A P, Taylor H, Warltier R, Oliver R G, Newcombe R G 1989 A clinical study of amount of adhesive remaining on enamel after debonding. Comparing etch times of 15 and 60 seconds. American Journal of Orthodontics and Dentofacial Orthopedics 95: 415–421

Maijer R, Smith D C 1982 Corrosion of orthodontic bracket bases. American Journal of Orthodontics 81: 43–48

Matis B A, Cochran M A, Eckert G, Carlson T A 1998 The efficacy and safety of a 10% carbamide peroxide bleaching gel. Quintessence International 29: 555–563

Sandisson R 1981 Tooth surface appearance after debonding. British Journal of Orthodontics 8: 199–201

Seghi R R, Hewlett E R, Kim J 1989 Visual and instrumental colormetric assessments of small color differences on translucent dental porcelain. Journal of Dental Research 68: 1760–1764

Silverstone L M, Saxton C A, Dogon I L, Fejerskov O 1975 Variation in the pattern of acid etching of human dental enamel examined by scanning electron microscopy. Caries Research 9: 373–375

Van Waes H, Matter T, Krejci I 1997 Three-dimensional measurement of enamel loss caused by bonding and debonding of orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 112: 666–669

Wozniak W T 1987 Proposed guidelines for the acceptance program for dental shade guide. American Dental Association, Chicago

Zachrisson B U, Årtun J 1979 Enamel surface appearance after various debonding techniques. American Journal of Orthodontics 75: 121–137