Enamel colour changes at debonding and after finishing procedures using five different adhesives

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SUMMARY The purpose of this study was to evaluate enamel colour alteration of five different orthodontic bonding adhesives by means of digital measurements after exposure to photoageing in order to simulate discolouration of adhesives *in vivo.*

Seventy-five non-carious premolars were randomly divided into five equal groups. The brackets were bonded with five different adhesives (Transbond XT, Eagle Bond, Light Bond, Blugloo, Unite) and subjected to artificial accelerated photoageing for 24 hours. The enamel surfaces were colourimetrically evaluated before bonding, following debonding and cleaning with a tungsten carbide bur, after polishing with Stainbuster, and after photoageing of the debonded enamel surface. The Commission Internationale de l'Eclairage(CIE) colour parameters ($L*a*b*$) were recorded and colour differences (ΔE) were calculated. The results were statistically analyzed using the Kruskall–Wallis test. Further investigation among subgroups was performed using Dunn's multiple correlation test ($P < 0.05$). The clinical detection threshold for ΔE value was set at 3.7 units.

ΔE values between the first and second measurements showed an increase in the Transbond XT, Eagle Bond, and Light Bond groups. The highest ΔE value was 1.51 ± 1.15 in the Transbond XT group. No clinically significant ΔE value was observed.

Colour changes of orthodontic bonding systems induced by photoageing cannot be clinically observed. Polishing with Stainbuster eliminates enamel surface roughness, which may improve light reflection.

Introduction

Since the introduction of the acid-etch technique (Buonocore, 1955) and its use for bonding of orthodontic brackets, one of the primary concerns is to return the enamel surface to as near its original state as possible with the minimum amount of enamel loss, at completion of fixed appliance therapy. Bonding, debonding, and clean-up procedures may result in enamel alterations such as microcracks and enamel fractures caused by forcibly removing brackets, as well as scratches, and abrasions caused by mechanical removal of the remaining composite materials (Pus and Way, 1980; Diedrich, 1981; Sandisson, 1981). A previous study has shown that enamel colour variables are affected by enamel bonding and debonding procedures (Eliades *et al.*, 2001). After removal of orthodontic appliances, a residual amount of adhesive usually remains on the surface (Kinch *et al.*, 1989). 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). Because resin impregnation into the enamel structure cannot be reversed by debonding and clean-up procedures (Øgaard *et al.*, 1998), some may be left even though a layer of enamel is removed (Zachrisson and Årtun, 1979). Enamel discolouration may occur by direct absorption of food colourants and products arising from the corrosion of the orthodontic appliance (Eliades *et al.*, 2004) even after orthodontic treatment. Also post-debonding protocols involving removal of adhesive residuals with various rotary abrasive tools or hand instruments may increase the roughness of the enamel surface that may lead to colour alterations (Eliades *et al.*, 2001).

Determination of tooth colour has always been problematic in dentistry. The modern approach to colour analysis is to define colours by value, chrome, and hue. The Commission Internationale de l'Eclairage (CIE, 1976) $L*a*b*$ mathematical system has been widely used for non-self-luminous objects such as textiles, paints, and plastic (McLaren, 1976; Agoston, 1979). This system has also been used in aesthetic dentistry. The $L*$ parameter corresponds to the value or degree of lightness in the Munsell system, ranging from 0 (black) to 100 (white); the $a*$ parameter is a measure of redness ($a > 0$) or greenness ($a < 0$) and the $b*$ parameter of yellowness ($b > 0$) or blueness ($b < 0$). As the ability of the human eye to detect colour changes has not been found to be reliable, this type of evaluation can be achieved by an instrumentation system that is able to resolve colours in a standardized manner (Pietrobon *et al.*, 2005).

Photoageing is a process involving exposure of the enamel surfaces to a 24 hour continuous illuminance of approximately 135 000 Lux at 400 nm. This procedure induces ageing equivalent to exposure to sun irradiation in Central Europe for 30 days (Atlas Suntest Bulletin, 1998). A previous study has shown that photoageing induced colour changes in some orthodontic adhesives (Maijer and Smith, 1982).

The purpose of this study was to investigate enamel colour alterations at debonding and after finishing procedures of five different orthodontic bonding adhesives by means of digital measurements after exposure to photoageing.

Materials and methods

One hundred and twenty-five non-carious premolars extracted from adolescent patients for orthodontic reason were collected. Teeth that had white spots, demineralization areas, fractures, abrasions, or microcracks were eliminated from the sample. Only 75 teeth were found to be adequate for the selection criteria used in this study. The teeth were prepared by cleaning the buccal surfaces with fine pumice slurry on a rotating brush for 30 seconds. The buccal surfaces of the teeth were black taped leaving the intersection between the middle, vertical, and middle mesiodistal thirds of the buccal surfaces open (bracket placement area). All measurements were performed at the exposed enamel window to standardize the enamel surface intended for analysis. The teeth were code numbered for identification and randomization. Enamel surfaces were colourimetrically evaluated by means of a colourimeter (Vita Easyshade, Vita Zahnfabrik, Bad Sackingen, Germany) according to the manufacturer's instructions by a single operator (GT). All measurements were carried out on wet enamel surfaces. Evaluations were performed employing a repeated measure design ($n = 5$) according to the CIE $L*a*b*$ system (Baltzer and Kaufmann-Jinoian, 2004).

The teeth were polished with non-fluoridated and oil-free pumice, rinsed, dried for 10 seconds and then randomly assigned to five groups of 15. The five different adhesives used in this study are listed in Table 1. The labial surfaces of all teeth were then etched with 38 per cent phosphoric acid etching gel (Etch-Rite) for 30 seconds, rinsed, and dried with oil-free compressed air. Light curing in groups 1–4 was performed with the same visible light-curing unit (Optilux™ XT, 3M Unitek).

The teeth were bonded according to the manufacturer's instructions. Upper premolar ceramic brackets (Illusion Plus, Ormco Corporation, Orange, California, USA) were placed and firmly pressed onto the enamel surfaces and excess adhesive was removed from the bracket base periphery. Transbond XT, Eagle Bond, and Light Bond were cured for 40 seconds and then Blugloo for 15 seconds as recommended by the manufacturers.

After bonding, all specimens were immersed in water for 48 hours and then subjected to artificial light (Sunset CPS plus, Atlas Material Testing Technology, Gelnhausen, Germany). All specimens were kept in artificial saliva for 10 days.

After photoageing, the brackets were mechanically debonded using a conventional bracket removal plier (Inspire Ice Debonding Kit, Ormco, Glendora, California, USA). Removal of the adhesive was carried out with a high-speed tungsten carbide finishing bur. A new bur was used for each tooth. A second colour determination was then performed and the enamel surface was polished with a composite bur (Stainbuster, Abrasive Technology, Inc., Lewis Center, Ohio, USA).

The clean-up was performed by a single operator (GT). The extent of the overall resin removal process was determined by visual inspection of the enamel surface by the same operator under a dental operating light.

After polishing, the enamel colourimetric measurement was again performed. A second photoageing process was undertaken after the polishing process followed by a fourth colourimetric measurement. The colour changes (ΔE) were computed from the single colour values $L*a*b*$ according to the following formula to determine the three-dimensional $L*a*b*$ colour space (International Organization for Standardization, 1985):

$$\Delta E = [(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2]^{0.5}$$

$\Delta L*$ indicates changes in value (lightness), $\Delta a*$ changes in the red–green parameter, and $\Delta b*$ changes in the yellow–blue parameter.

Table 1 Bonding systems used in the five groups.

Material		Manufacturer
Phosphoric acid	38%	Etch-Rite Etchant gel, Pulpdent, Watertown, Massachusetts, USA
Transbond XT Light cure adhesive	30 seconds	3M Unitek, Monrovia, California, USA
Ligth cure (Optilux™ XT)	40 seconds	3M Unitek
Phosphoric acid	38%	Etch-Rite Etchant gel
Eagle Bond	30 seconds	American Orthodontics, Sheboygan, Wisconsin, USA
Light cure (Optilux™ XT)	40 seconds	3M Unitek
Phosphoric acid	38%	Etch-Rite Etchant gel
Blugloo	30 seconds	Ormco, Scafati, Italy
Light cure (Optilux™ XT)	15 seconds	3M Unitek
Phosphoric acid	38%	Etch-Rite Etchant gel
Light Bond	30 seconds	Reliance Orthodontic Products Inc., Itasca, Illinois, USA
Light cure (Optilux™ XT)	30 seconds	3M Unitek
Phosphoric acid	38%	Etch-Rite Etchant gel
Unite	30 seconds	3M Unitek

Statistical analysis

Statistical analysis was performed using the NCSS-PASS statistical software package version 2007 (Kaysville, Utah, USA). In addition to standard descriptive statistical calculations (mean and standard deviation), a non-parametric Friedman test was used for analyzing consecutive measurements. For inter-group comparison, a non-parametric Kruskal–Wallis test was used. Differences among subgroups were further investigated using the *post hoc* Dunn's multiple comparison test. Intraclass correlation coefficient (ICC) was used to measure reliability among repeated measurements. The statistical significance level was established at $P < 0.05$. The results were evaluated within a 95 per cent confidence interval. The clinical significance of colour difference level was set at 3.7 CIE $L^*a^*b^*$ units.

Results

The ICC for the repeated measurements was over 0.90, indicating excellent reliability. The mean values for each bonding agent at each time point is shown in Table 2. There was a statistically significant difference between the groups bonded with Transbond, Eagle Bond, and Reliance (Table 2). This difference was as a result of the increase in ΔE values between the first and second measurement. For the Reliance group only, a significant difference existed between the second and third and second and fourth measurements. No difference was observed in groups bonded with Blugloo and Unite.

Discussion

In this study, artificial photoageing was used to simulate colourations that may take place in the oral cavity. However, it must be noted that long-term resin discolouration induced by absorption of colourants from the oral environment

cannot be estimated. In order to gain more reliable results, an *in vivo* investigation must be undertaken.

Changes in the present study were evaluated digitally using the Vita Easyshade. It has been reported that this is one of the most reliable and precise devices for indicating tooth colour (Baltzer and Kaufmann-Jinoian, 2005; Dozić *et al.*, 2007).

In the present investigation all ΔL values were less than 2.0 units. The ΔL^* is the most significant parameter because the human eye can detect changes in L^* more readily than it can perceive changes in the other parameters such as a^* and b^*. All ΔL^* values less than 2.0 units (Paul *et al.*, 2002) and total ΔE values less than 3.7 units have been shown to represent clinically acceptable matching (Johnston and Kao, 1989) and are not clinically visible. Although it has been suggested that differences in ΔE exceeding 2 units may indicate change (Wozniak, 1987) some studies set the proposed acceptance limit for matching to 3.7 units, beyond which the differences are clinically visible (Johnston and Kao, 1989). Um and Ruyter (1991), referring to the findings of Kuehni and Marcus (1979) and Ruyter *et al.* (1987), assume, in dental science, an awareness of a difference of $\Delta E > 1$. They claim acceptable values of $\Delta E < 3.3$ for differences in natural teeth and in filling materials, i.e. in simple, flat surfaces. In the present study, the highest ΔE value was 1.51 ± 1.15 observed in the Transbond group at the second measurement. Therefore, the highest statistically significant value detected is in fact clinically not visible by the human eye. Eliades *et al.* (2004) demonstrated, using digital colourimetric measurements, that Transbond XT showed no clinically significant ΔE value after being subjected to artificial photoageing. The results of the present study parallel their findings. However, it is not accurate to make such a comparison because Eliades *et al.* (2004) used only adhesive discs. In another study, where Unite was used as the adhesive resin, it was suggested that photoageing induced further changes in the ΔE values of the debonded surfaces above the colour difference threshold of 3.7 units

Table 2 Delta E (ΔE) measurements for all groups. ΔE 1, ΔE 2, ΔE 3, and ΔE calculated for the first, second, third, and fourth colourimetric measurement.

ΔE	Transbond XT	Eagle Bond	Blugloo	Light Bond	Unite	P value	Significance
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD		
ΔE 1	0.57±0.54	0.44±0.28	0.44±0.31	0.65±0.47	0.65±0.31	0.061	NS
ΔE 2	1.51±1.15	1.26±1.39	1.04±0.94	1.09±0.66	0.85±0.5	0.509	NS
ΔE 3	0.54±0.35	0.48±0.39	0.53±0.31	0.53±0.4	0.47±0.26	0.822	NS
ΔE 4	0.56±0.25	0.51±1.14	0.56±0.38	0.58±0.37	0.51±0.32	0.828	NS
P value	0.022	0.015	0.549	0.006	0.155		
Significance	*	*	NS	**	NS		

SD, standard deviation; NS, not significant.*$P < 0.05$; **$P < 0.01$.

(Eliades *et al.*, 2001). The significant colour change found only for the Reliance group between the second and third and second and fourth measurements in the present research may be due to the different chemical properties of the adhesives. Further investigations are required to confirm the relationship between enamel surface roughness and colour stability.

Colour measurements are performed by reflected light which is a surface roughness-dependent parameter and highly sensitive to surface alteration influencing the L^* values of the samples (Chung, 1994; Leibrock *et al.*, 1997). A direct relationship has been found for opacity and L^* in resin composite and resin-modified glass ionomers (Omomo *et al.*, 1989). Surface roughness affects random specular reflection of light that leads to a white appearance (Saton *et al.*, 1989). In the present study, the difference between $\Delta E1$ and $\Delta E2$ in the Transbond, Eagle Bond, and Reliance groups could be related to surface roughness caused by adhesive removal with a tungsten carbide bur. Although it has been shown that the least enamel loss was after use of a tungsten carbide bur in a slow-speed hand piece (Hosein *et al.*, 2004), it has been suggested (Zarrinnia *et al.*, 1995) that a tungsten carbide bur at a high speed followed by various grades of Sof-Lex discs and finally a zircate paste should be used. Jarvis *et al.* (2006) concluded that orthodontic bonding altered the porcelain surface which affected the cosmetic appearance of the restorations, and that polishing after debonding did not restore the surface to the pre-bond state. In the present study, a tungsten carbide bur at high speed, followed by Stainbuster was used. No study has previously been undertaken to determine the relationship between enamel surface roughness and changes. Further research is needed.

There was no significant difference between $\Delta E3$ and $\Delta E4$ values. This finding indicates that photoageing performed following debonding did not cause any colour changes, however considering that enamel discolouration may occur by direct absorption of food colourants (Eliades *et al.*, 2004) even after orthodontic treatment, long-term clinical studies are necessary to verify this.

Conclusions

Despite potential methodological limitations, based on the study results, the following conclusions may be drawn:

1. Colour changes of orthodontic bonding systems induced by photoageing cannot be clinically observed.
2. Clean-up performed only using tungsten carbide burs may lead to increased enamel surface roughness.
3. Polishing with Stainbuster eliminates enamel surface roughness, which may improve reflection of light.
4. Photoageing performed after debonding has no influence on enamel surface colour.

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