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Journal of Contemporary Orthodontics

Journal homepage: https://www.jco-ios.org/

Original Research Article

Evaluating the effectiveness of color changing adhesives versus ultraviolet absorbent dye additive adhesives in the removal of adhesive remnants after orthodontic debonding

Udhayan Asokan[1]*, Hanumanth Sankar[1], Sabarinathan Jaganathan[1], Aniruddh Yashwant[2], Thangabalu Rajamuthu[1], Lidhiya Alexander[2], Arun V[2]

[1]*Dept. of Orthodontics and Dentofacial Orthopaedics, Vinayaka Mission's Sankarachariyar Dental College, A Constituent College of Vinayaka Mission's Research Foundation (Deemed to be University), Ariyanoor, Tamil Nadu, India*
[2]*Dept. of Orthodontics, Indira Gandhi Institute of Dental Sciences, A Constituent College of Sri Balaji Vidyapeeth Deemed to be University, Puducherry, India*

ARTICLE INFO

Article history:
Received 14-03-2024
Accepted 28-04-2024
Available online 27-08-2024

Keywords:
Adhesive remnant index
Colour changing orthodontic adhesives
Enamel damage index

ABSTRACT

Introduction: The fixed orthodontic treatment initiates with bonding and ends up with debonding of brackets which alters the enamel surface. The adhesive remnants present on the enamel surface after debonding are removed with the help of various aids but alters the enamel surface to an extent and there is no alternative material or instrument for removing the adhesives.
Aim: The aim of the study was to compare the effectiveness of color changing orthodontic bonding adhesives versus ultraviolet absorbent dye additive orthodontic bonding adhesives in the removal of adhesive remnants after orthodontic debonding.
Materials and Methods: 40 extracted human premolars were procured and metal brackets were bonded to the buccal surface with Group 1 – Enlight, Group 2 – Grengloo, Group 3 - Brace Paste & Group 4 – Enlight + UV dye additive. Debonding of brackets were done in INSTRON and evaluated for ARI score in stereo microscope and photo micrographs were taken to analyze the surface area in ImageJ software with conventional and UV light source. Then the adhesive remnants were removed with tungsten carbide bur at low speed with appropriate illumination and the enamel surface is assessed under scanning electron microscope for EDI score.
Results: This study resulted with time taken for the removal of adhesive remnants between the 4 groups and indicates statistically significant difference ($p<0.05$). Group 3 (Brace Paste) possesses the less time taken for the removal of adhesive remnants between the other three groups and shear bond strength reveals a statistically significant difference ($p<0.05$) between the three adhesive groups.
Conclusion: This current study concluded that the color changing adhesives with the fluorescence property were significantly different when compared with other adhesives due to the reduction in time taken for the removal of adhesive remnants from the enamel surface with minimal damage. Additionally the introduction of a UV dye additive for the visual distinction between the enamel structure and adhesive remnant also proves to be a valuable aid in the assessment of adhesive remnant index and removal.

1. Introduction

The fixed orthodontic treatment initiates with the bonding of brackets and attachments for orthodontic tooth movement

* *Corresponding author*.
E-mail address: hanumanth001@gmail.com (U. Asokan).

https://doi.org/10.18231/j.jco.2024.039

and it terminates with the removal of those brackets and attachments from the surface of the teeth. Bonding of brackets must ensure a good shear bond strength and low bond failure to the orthodontic forces that are applied during orthodontic tooth movement and the forces of mastication on the teeth surface.[1,2] Therefore, this bond strength should cause no or minimal enamel damage while removal of the brackets from the enamel surface after treatment completion.

Various methods of debonding techniques are practiced and the common method of debonding is done with pliers which apply a shear or tensile force to the bonded surface without any potential damage to enamel. Unfortunately there is no standard protocol for the debonding procedure.[3,4] While debonding there is minimal enamel damage which is inescapable because of the micro-mechanical bond between the etched enamel and adhesive utilized for orthodontic bonding. While removing the brackets from the teeth structure there is a bond failure occurring between adhesive-enamel or adhesive-bracket interface (adhesive failure) or within the adhesive (cohesive failure). Usually, the combination of adhesive-enamel failure occurs leaving a considerable amount of adhesive remnants on the enamel surface.[5] Metallic orthodontic brackets are widely used for fixed orthodontic treatment and the cris-cross wire mesh fused to the base of the metal brackets provide for mechanical interlocking of metal brackets to the composite resin and hence constituting to a clinically efficient adhesion between bracket base-adhesive-enamel.[6]

Artun and Bergland used Adhesive Remnant Index (ARI) system to measure the amount of adhesive left on the enamel surface after debonding. The differences in ARI scores reflect a difference in bond strength between the enamel and the adhesive. The complete removal of adhesive remnants is an important procedure because it results in excessive plaque accumulation, periodontitis, white spot lesions and enamel discoloration. For achieving a complete removal of adhesive remnants from the tooth surface with negligible damage to the enamel surface, the Orthodontists must take adequate care to remove the adhesive remnants from the enamel surface. This procedure involves a high challenge due to the shade similarities between enamel surface and adhesives as noted by various studies in Orthodontics and Restorative dentistry forums.[7–9]

The fluorescent material used in the study emits more visible light than it receives and thus they are utilized for distinguishing the enamel surface and the adhesives for identifying and removal of the adhesive remnants.[9] Various authors and studies have evaluated UV light source as an aid for detecting the composite restoration in Dentistry journals and forensic investigations.[3,10,11] The objective of this study was to compare the effectiveness of color changing bonding adhesives versus UV absorbent dye additive adhesives in the removal of adhesive remnants after orthodontic debonding.

2. Materials and Methods

This in-vitro study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, in tertiary dental college and Department of Manufacturing Engineering and Centralized Instrumentation and Service Laboratory (CISL) in a government affiliated laboratory. Prior to the start of the study the approval was obtained from the Institutional Ethics Committee *(IGIDSIEC2020NRP25PGUDODO)].* Based on the findings from Connie Lai and associates sample size was calculated using the formula - $n = (Z\sigma/E)^2$ (α = 0.05 , Z = 1.96 , σ= 0.08 , E = 0.05), power of 95% to detect a difference greater than 0.5 mm^2, and a standard deviation of 0.4 mm^2. A sample size of 10 premolar teeth was found to be adequate for each group. Therefore, 40 extracted premolar teeth from patients undergoing therapeutic extractions during Orthodontic treatment were collected. Only teeth with normal tooth morphology, intact buccal enamel, devoid of caries, plaque and calculus were included and teeth treated with chemical agents and visible cracks were excluded. Conventional metal brackets with MBT prescription 0.022" slot were bonded by a single trained investigator with different orthodontic bonding adhesives to the buccal surface of the premolars which were divided randomly into four different groups as mentioned in (Table 1). Teeth from each group were cleaned with water to remove blood stains and tissue remnants which were then polished with ICPA Smile and Shine Polishing kit. Each tooth was mounted on an acrylic block (15×10cm), such that the facial surface of the premolar teeth is perpendicular to the base of the acrylic block.

The enamel surface of each sample was conditioned with 37% Phosphoric acid (EZ Etch) for 30 seconds as instructed by the manufacturer and rinsed with water for 10 seconds. Following the brackets were bonded in each group with respective adhesives (Figures 1 and 2), (Table 1). All the samples were placed in a closed container under distilled water for 24 hours before debonding procedure was carried out.

The samples were fixed in the lower jaw of INSTRON (Universal Testing Machine) (Figure 3) and debonded by a sharp pointed device loaded on the upper jaw which moved at a crosshead speed of 1.0 mm/min for debonding of the brackets to standardize the debonding force (1.0 k N) employed during debonding procedure. The tooth surface after debonding procedure were subjected to stereomicroscope and microphotographs were obtained to measure the adhesive remnant index (ARI) score according to Artun J, Bergland (score 0 – no adhesive left on tooth, score 1 - <50% of adhesive on tooth, score 2 - > 50% adhesive left on tooth, score 3 – all adhesive left on tooth), (Figure 4).

The enamel surface with adhesive remnants were removed thoroughly with Tungsten Carbide (12-bladed, SYNDENT) bur in a low speed hand-piece by utilizing the light sources for the specific groups and the time taken for the removal was noted by the same investigator with an assistant to hold the UV flashlight from the point of applying the bur to the end of removal of adhesives. (Table 1), (Figures 5 and 6).

The tooth surface after adhesive removal were subjected to stereomicroscope for assessing the adhesive remnant index score for each specimen and photographs were obtained and the images were scaled for the surface area of adhesive remnants which was again traced and calculated using Image J software (National Institutes of Health, Rockville) precisely marked with the end points of the adhesive remnants and joined them to obtain the surface area of the adhesive remnants with respect to length and breadth (Figure 7). All measurements were made twice, 1 week apart by the same trained operator. The repeated measurements were used for assessing intra-rater reliability, and the average was used in the statistical analysis. For assessment under Scanning Electron Microscope (JSM-IT200, In Touch Scope ^{TM}). The enamel damage score in all the samples were evaluated according to Howell and Weekes (grade 0 – smooth surface, no scratches, grade 1 - acceptable surface, fine scratches, grade 2 – rough surface, coarse scratches, grade 3 – very rough surface, deep scratches visible in naked eye), (Figure 8).

2.1. Statistical analysis

All statistical analyses were performed using the SPSS software. One way ANOVA and Post – Hoc tukey test were used to assess the difference in continuous variables between different groups. Chi square test was used to assess the difference in categorical variables in different groups. p -value of <0.05 was accepted as statistically significant.

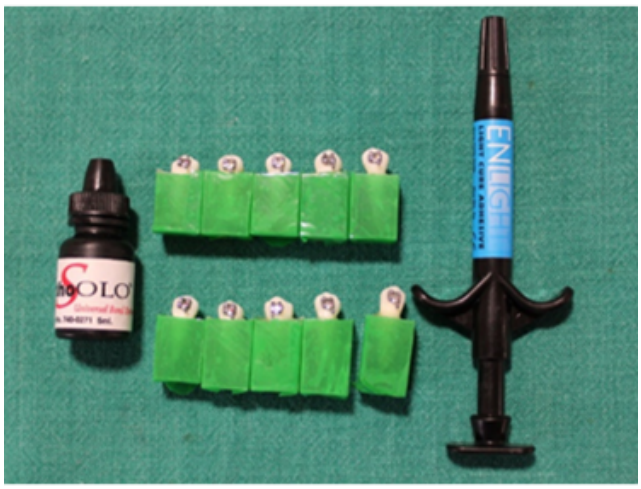

Figure 1: Group1 (Enlight + Ortho Solo)

Figure 2: Group2 (Grengloo + Ortho Solo)

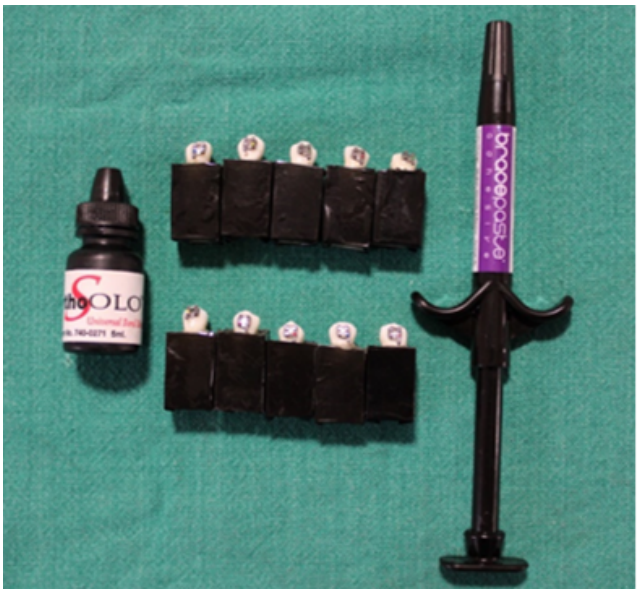

Figure 3: Group3 (Brace Paste + Ortho Solo)

Table 9 denotes the mean, standard deviation of the surface area of adhesive remnants present on the tooth surface after debonding of the attachments. Group 1exhibits the highest mean surface area when compared with the other groups. The surface area of adhesive remnants present over the tooth surface between the groups reveals no statistically significant difference. (p>0.05).

3. Results

Table 1 shows descriptive statistics of mean and standard deviation of shear bond strength between groups. Inferential

Table 1: Experimental groups

Groups	Bonding adhesives	Evaluating light source
Group 1	Enlight (ormco)	Conventional yellow light
Group 2	Grengloo (ormco)	Conventional yellow light
Group 3	Brace paste (american orthodontics)	Ultra violet light – 395 nm
Group 4	Enlight (ormco) with uv dye additive (uv lipstick - moon glow) incorporated with primer	Ultra violet light – 395 nm

Table 2: ARIindex

Score 0	No adhesive left on the tooth,
Score 1	Less than half of the adhesive left on the tooth
Score 2	More than half of the adhesive left on the tooth
Score 3	All adhesive left on the tooth with distinct impression of the bracket mesh

Table 3: EDIindex

GRADE 0	Perfect and smooth surface. No scratches, distinct intact perikymata;
GRADE 1	Satisfactory surface. Fine scratches, some perikymata;
GRADE 2	Acceptable surface. Several marked and some deeper scratches, no perikymata;
GRADE 3	Imperfect surface. Several distinct deep and coarse scratches, no perikymata;

Table 4: The mean shear bond strength and standard deviation of orthodontic adhesives

		Mean (MPa)	Std. Deviation	F - value	p - value
Group – 1	10	14.0090	1.02569		
Group – 2	10	22.0820	1.60458	100.685	<0.001
Group – 3	10	17.4550	1.12369		

*(Group 1 -Enlight, Group 2 – Grengloo, Group 3 – Brace paste)

Table 5: Post hoc test

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Group - 1	Group – 2	-8.07300	<0.001
	Group – 3	-3.44600	<0.001
Group - 2	Group – 3	4.62700	<0.001

*(Group 1 -Enlight, Group 2 – Grengloo, Group 3 – Brace paste)

Table 6: The mean time taken for adhesive removal, Standard deviation and Standard error values of time taken for removal of adhesive remnants after debonding.

		Mean (seconds)	Std. Deviation	p - value
Group 1	10	10.1410	1.02024	0.033
Group 2	10	9.6210	1.50655	
Group 3	10	8.5450	1.50945	
Group 4	10	8.8160	1.02140	

*(Group1 - Enlight, Group 2 – Grengloo, Group 3 – Brace paste, Group 4 – Enlight withUV additive)

Table 7: : Post– Hoc tests

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	.52000	.57586	.845	-1.1686	2.2086
	Group 3	1.59600	.57586	.043	-.0926	3.2846
	Group 4	1.32500	.57586	.171	-.3636	3.0136
Group 2	Group 3	1.07600	.57586	.337	-.6126	2.7646
	Group 4	.80500	.57586	.587	-.8836	2.4936
Group 3	Group 4	-.27100*	.57586	.974	-1.9596	1.4176

*(Group1 - Enlight, Group 2 – Grengloo, Group 3 – Brace paste, Group 4 – Enlight withUV additive)

Table 8: ARI score distribution and Chi – square test

			Ari Score				Total	Chi-square value	p-value
			0	1	2	3			
GROUP	1	Count	1	5	3	1	10	2.882	0.969
		%	10.0%	50.0%	30.0%	10.0%	100.0%		
	2	Count	2	5	3	0	10		
		%	20.0%	50.0%	30.0%	.0%	100.0%		
	3	Count	2	4	4	0	10		
		%	20.0%	40.0%	40.0%	.0%	100.0%		
	4	Count	2	4	3	1	10		
		%	20.0%	40.0%	30.0%	10.0%	100.0%		
Total		Count	7	18	13	2	40		
		%	17.5%	45.0%	32.5%	5.0%	100.0%		

*(Group1 - Enlight, Group 2 – Grengloo, Group 3 – Brace paste, Group 4 – Enlight withUV additive)

Table 9: The mean area and standard deviation values ofsurface area of adhesive remnants present on the tooth surface after debonding.

		Mean	Std. Deviation	p - value
Group 1	10	3.5700	1.54146	0.878
Group 2	10	3.0330	1.63750	
Group 3	10	3.4270	1.79859	
Group 4	10	3.5650	1.75063	

*(Group1 - Enlight, Group 2 – Grengloo, Group 3 – Brace paste, Group 4 – Enlight withUV additive)

Table 10: EDI score distribution and Chi – square test

			EDI Score				Total	Chi – square test	p - value
			0	1	2	3			
Group	1	Count	3	5	2	0	10	2.242	.896
		%	30.0%	50.0%	20.0%	0.0%	100.0%		
	2	Count	4	4	2	0	10		
		%	40.0%	40.0%	20.0%	0.0%	100.0%		
	3	Count	3	6	1	0	10		
		%	30.0%	60.0%	10.0%	0.0%	100.0%		
	4	Count	2	7	1	0	10		
		%	20.0%	70.0%	10.0%	0.0%	100.0%		
Total		Count	12	22	6	0	40		
		%	30.0%	55.0%	15.0%	0.0%	100.0%		

(Group 1 - Enlight, Group 2 –Grengloo, Group 3 – Brace paste, Group 4 – Enlight with UV additive)

Figure 4: Group4 (Enlight + Ortho Solo + UV dye)

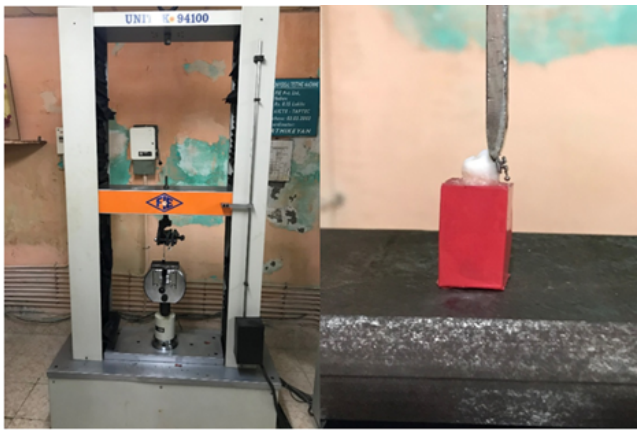

Figure 5: Deboning– Universal testing machine

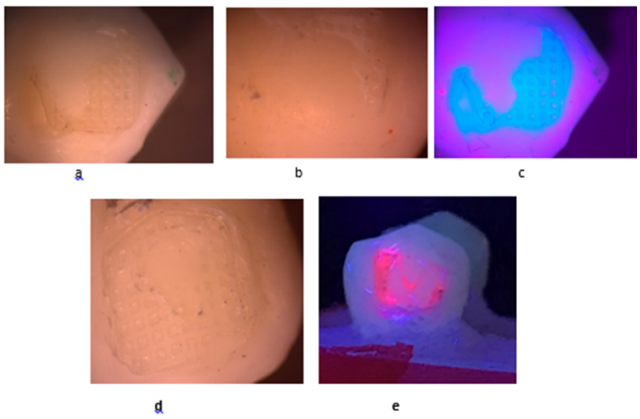

Figure 6: a: Group 1 – Enlight **b**: Group 2 – Grengloo **c:** Group 3 – Brace Paste under UV illumination **d:** Group 4 – Enlight + UV dye **e:** Group 4 – Enlight + UV dye + UV flashlight illumination

Figure 7: UVdye lipstick and UV flash light

Figure 8: Adhesiveremnant removal

Figure 9: Tungsten carbide bur

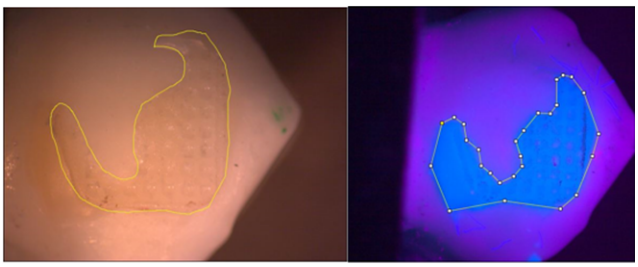

Figure 10: Adhesive remnant measurement in Image J software

statistics using post hoc tukey test showed the shear bond strength between the three groups were statistically significant ($p<0.05$). Group 2 showed highest shear bond strength between the groups. (Table 2)

Table 3 shows time taken parameter for the removal of adhesive remnants between the groups and indicates a statistically significant difference ($p<0.05$). Group 3 showed the least time taken for the removal of adhesive remnants between the groups. (Table 4) Frequency distribution of adhesive remnant index score, enamel damage index scores and descriptive analysis of surface area evaluation revealed a statistically insignificant difference between the experimental groups. (Tables 5, 6 and 7)

4. Discussion

The fixed orthodontic treatment initiates with bonding of brackets for orthodontic tooth movement and the treatment terminates with the debonding of the bonded

Figure 11: Scanningelectron microscope

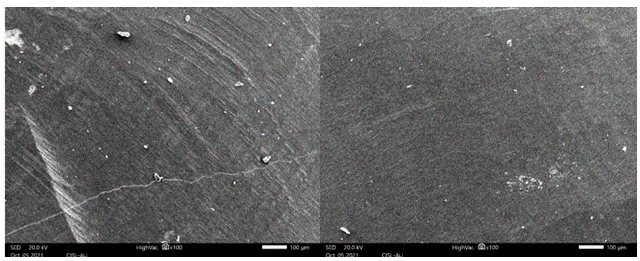

Figure 12: Scanningelectron microscope evaluation

brackets from the enamel surface. The adhesive remnants present over the enamel surface after the debonding procedure lead to the accumulation of plaque and calculus, esthetically compromised appearance, white spot lesions etc. Therefore the knowledge on adhesive remnant removal after debonding procedure in fixed orthodontic treatment has not been clear till now and there is no standard protocol to remove the remnants completely from the enamel surface. Thus the current study was designed to compare and evaluate the effectiveness between the color changing orthodontic bonding adhesives and the UV dye additive orthodontic bonding adhesives in the removal of adhesive remnants (AR) after debonding.

4.1. Ari evaluation

The resultant ARI score was recorded as score 1 and 2 predominantly (Table 6) similar to the study performed by Mona et al (2009) and Gruheid et al (2015).[8,12]

For more precise removal of adhesive remnants and their clear and distinct visualization, in the current study the introduction of a new visualizing aid – UV dye additive a dye extracted from a lipstick (Neon UV lipstick – MOON creations) were applied over the adhesives which showed the enamel surface and adhesives distinctly facilitating less damage to the enamel surface while removing the adhesive remnants. The lipstick included in the current study was a FDA-Approved and bio-compatible one.

4.2. Surface area and time evaluation

The photomicrographs obtained from Stereomicroscope were evaluated in ImageJ software as in accordance with the study performed by Connie et al (2019).[13] There was no significant difference ($p>0.05$) in the surface area of the adhesive remnants over the enamel surface between the groups. Ahari et al.[14] in a study stated that removal of adhesive remnants with the help of Tungsten carbide bur at a low speed was the safest procedure compared to various methods of adhesive remnant removal from the enamel surface area. Hence the removal of adhesive remnants reduced the enamel damage and the time duration was reported in our current study between the groups.[15] Oliver et al.[16] claimed high difference in time taken for the removal of adhesive remnants (65.9 seconds vs 191 seconds) when two different operators with different experience levels were assigned. So the current study was in accordance with the previous studies assigned a single operator to eliminate inter-operator reliability.

4.3. Enamel damage index evaluation

The resultant EDI score was recorded as score 1, score 0 and followed by score 2. The statistics for the enamel damage index score had no significant difference between the groups ($p>0.05$) which were similar to the previous literatures reported by Arbutina *et al (2018)* and Jacqueline et al (2020).[15,17] Pus and Way[18] also concluded in a similar study there was a lesser amount of enamel damage evident while using TC bur at low speed. Ribeiro et al[9] and Kaneshima et al[19] stated in their studies that the use of UV flashlight source for illuminating the adhesive remnants during the removal procedure which resulted in least reduction of enamel loss than it did with the conventional light source.

The current study findings also stated that the use of rotating instruments for adhesive remnants removal procedures caused minimal abrasion on the enamel surface that was proportional to the shape and size of the abrasive particles present on the rotating instrument. Therefore no instrument can result in complete removal of adhesive remnants and however the alteration found on the enamel surface in the current study was not severely affected to alter the integrity of the enamel surface.[5]

An additional finding was observed on evaluating the shear bond strength between the conventional orthodontic adhesives and color changing orthodontic adhesives and stated that the color changing orthodontic adhesives possess higher shear bond strength than that of the conventional orthodontic adhesives. Orthodontic adhesives in general are manufactured with higher shear bond strength when compared with the optimum shear bond strength given by Reynold *et al* (1978) of 6 to 8 MPa as mentioned in his classical works.[20]

4.4. Limitations of the study

This in- vitro research study was done to simulate the beneficial aids to the clinical scenario in future years for excellent patient care and delivering best treatment results for the patients undergoing orthodontic treatment. However, it is hard to extrapolate the results which have been obtained in the in-vitro study conditions to an in-vivo study conditions it could be used as a resource for the future studies.

5. Conclusion

The current study concluded with the introduction of a new auxiliary and a bio - compatible additive (UV dye additive) for the removal of adhesive remnants from the enamel surface with clear visual distinction between the enamel surface and the adhesive and the color changing bonding adhesives included in the study has their own unique property of color change and fluorescence which has been incorporated in the material which resulted in reduction in time taken for the removal of the adhesive remnants without any potential enamel damage respectively. Future research with the available resources would benefit the Orthodontists and the patients as well for betterment in treatment outcome.

6. Source of Funding

None.

7. Conflict of Interest

None.

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Author biography

Udhayan Asokan, Assistant Professor https://orcid.org/0000-0001-6746-4238

Hanumanth Sankar, Associate Professor https://orcid.org/0000-0003-0043-715X

Sabarinathan Jaganathan, Professor

Aniruddh Yashwant, Associate Professor https://orcid.org/0000-0003-1045-6258

Thangabalu Rajamuthu, Assistant Professor https://orcid.org/0009-0005-7712-2692

Lidhiya Alexander, Associate Professor

Arun V, Consultant Orthodontist

Cite this article: Asokan U, Sankar H, Jaganathan S, Yashwant A, Rajamuthu T, Alexander L, Arun V. Evaluating the effectiveness of color changing adhesives versus ultraviolet absorbent dye additive adhesives in the removal of adhesive remnants after orthodontic debonding. *J Contemp Orthod* 2024;8(3):258-266.