



Original Research Article

Fluorescence behaviour of flowable adhesives for attachment removal in clear aligner therapy: An in-vitro study

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Abstract

Background: The study was conducted to compare fluorescence behaviour of four different commercially available flowable composite materials and to compare enamel loss and residual material of these composites in clear aligner therapy.

Fluorescence is a property of a substance that absorbs light and within 10 sec of activation, spontaneously emits light at a larger wavelength which is useful for adhesive identification during removal.

Materials and Methods: For the in-vitro study, 84 extracted premolar teeth were taken. The attachments were placed with the help of four different adhesives. The fluorescence of the composites was measured on the clinical photographs by using Colour-picker tool. The tungsten carbide bur with low-speed hand-piece was used to remove the composite under fluorescent light emitting diode (LED) (405 ± 10 nm). The volumetric analysis of the enamel surface and adhesive was done by superimposition of the pre and post scans with the help of Omnicam software.

Results: The fluorescence was highest in G-aenial universal flow [98.00 ± 0.816], followed by Tetric N flow [95.00 ± 0.816], Polofil NHT Flow [94.5 ± 1.914], and was minimum in Filtek Supreme ultra flowable [52.50 ± 4.509]. Enamel loss [1.35 ± 0.460] and adhesive remaining [1.35 ± 0.460] was highest in Filtek Supreme ultra flowable (p-value<.05).

Conclusion: The difference in fluorescence of commonly used flowable composites was seen both clinically and statistically. G-aenial universal flow showed the best results with minimum enamel loss and residual adhesive.

Keywords: Fluorescence Aided Identification Technique, Attachments, Enamel loss, Colour saturation

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1. Introduction

Orthodontic treatment has become common in modern society. Similar to other dental specialties, Orthodontics is constantly driven to streamline technical processes in order to accomplish objectives with high quality and less discomfort. In the past, brackets were fixed onto bands that encircled the teeth, but in contemporary procedures, direct bonding of brackets on the tooth surface is done utilising a variety of adhesives.¹ These adhesives are removed after completion of the treatment without harming the underlying enamel while providing a strong enough bond to endure masticatory forces.² The composites were bonded to enamel surface by mechanical locking created between the micro porosities of enamel caused by conventional etching and the bracket base meshwork.¹

Success of dental treatment is dependent on aesthetics, and in recent years, demand for improved appearances has risen significantly.² The clear aligner treatment has become more popular recently as a result of patients' increased appreciation for thermoformed splints due to their superior comfort and appearance compared to traditional fixed orthodontic appliances. In 1998, Align Technology introduced Clear Aligners, which are designed to be worn sequentially by patients to achieve desired orthodontic outcomes.³

Composite resin is bonded to the tooth surface to form attachments. These attachments play a crucial role in clear aligner treatment, enhancing the aligners' ability to achieve precise tooth movements.⁴ Auxiliaries like bite ramps, composite attachments, power ridges, and precise cuts have

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been introduced by manufacturers in response to patient's interest which has enabled them to improve the beneficial qualities of these products and treat different types of malocclusions with aligners. Composite attachments allow for more controlled and active tooth movement, resulting in a more natural-feeling motion of the teeth.⁴

After clear aligner treatment, the last step needed to restore the surface of enamel to its normal state compared to the pretreatment is removing all the attachments and resin from the tooth surface. Numerous researchers have developed various methods for removing resin and polishing enamel afterward without resulting in iatrogenic harm. These methods include using Sof-Lex discs and scraping of adhesive with a scaler and removing resin with tungsten carbide burs and use of diamond finishing burs and specialized composite finishing burs. Additionally, recent methods include carbon dioxide and Yttrium–Aluminium–Garnet (Er: YAG) laser, ultraviolet light (UV). Abrasion techniques using aluminium oxide particles in the air and ultrasonic applications have been studied as substitutes for adhesive residue removal.^{4,5}

Several efforts are made to preserve the enamel's fluoride and mineral composition and reduce damage to enamel surface. Nevertheless, taking great care throughout the removal process runs the risk of not completely removing all adhesive resin, which creates two serious issues. Firstly, there's a chance that roughened areas could encourage the development of dental plaque which could lead to demineralisation and decaying lesions. Secondly the discolouration of composite residues over time. Insufficient removal of resin leaves behind areas of residual resin, leading to structural changes on the buccal surface and eventually compromising patient's aesthetics and overall oral health, which results in an unesthetic appearance.^{6,7} Also completely removing these adhesives is of more importance as these remnants can cause white spot lesions, periodontal inflammation and discoloration of enamel.⁸

There is still disagreement on the best methodology for eliminating resin residue, even after various research on the subject have been published.

Fluorescence is a property by which a substance absorbs light and within 10 sec of activation, spontaneously emits light at a larger wavelength. Many composite materials exhibit fluorescence properties that differ from those of dental hard tissues when exposed to visible light within a wavelength range of 405 ± 10 nm. The fluorescence-aided identification technique (FIT), which uses blue light source, is a helpful technique for distinguishing resin composites from tooth material.⁹

Composition of resin materials contains inorganic filler particles embedded within an organic resin matrix to provide good aesthetics under natural lightening. Fluorescent additives, such as rare-earth oxides (e.g., europium, cerium,

and ytterbium), are added to glass fillers to replicate the natural luminescent properties of teeth.⁹ In addition to improving aesthetic outcomes, these fluorescent additives help detect and remove composite restorations more easily. Nearly, 80% of commercially available composite materials exhibit fluorescence property that is higher than enamel or dentin's natural fluorescence property.

However, fluorescence identification technique has a few drawbacks. If the resin exhibits less fluorescent property, it can be detected only in a dark environment. Also, UV LED can affect the eyes. Additionally, while bonding procedure the technique cannot be used as a source of detecting excess adhesive as the light can lead to curing of resin.¹⁰

This study was conducted to study the fluorescence behaviour of adhesives for removing the attachments in clear aligner therapy after the completion of treatment without damaging enamel.

2. Materials and Methods

2.1. Sample size

The sample size was calculated using G* Power 3.1.9.7 software.

2.2. Inclusion criteria

Intact premolar teeth which were extracted for Orthodontic purpose.

2.3. Exclusion criteria

Extracted teeth with any staining, demineralisation, caries, enamel cracks and fractures.

84 intact Premolar teeth without any stains and enamel cracks which were extracted for the orthodontic treatment were procured. The extracted premolar teeth were stored in 0.5M chloramine T solution.

Four different flowable composite materials were selected and four groups were formed according to the composite material used for placing attachments for clear aligner therapy. Group A- Tetric N flowTM (Ivoclar Vivadent) composite attachments, Group B- Polofil NHT FlowTM (VOCO GmbH) composite attachments, Group C- G-aenial universal flowTM (GC America) composite attachments, Group D- Filtek Supreme ultra flowableTM (3M ESPE) composite attachments. (Figure 1)

The extracted premolar teeth were taken and arranged in the form of upper and lower arches (Figure 2). The upper and lower arch 3-D surface scans were made preoperatively with the help of intraoral scanner (Dentsply Sirona) for later pre and post scans superimposition. Another digital scan was made for preparing templates for placement of attachments in clear aligner therapy. The STL (Stereolithography) file was transferred to the software (Archform v2.3). Using the digital ruler, shell size of 2x2 mm area and 1mm thickness was

designed for each tooth (**Figure 3 (a)**). The tray was then thermoformed over shell model. Later trimmed at the top of the shells for easy removal from the arch (**Figure 3 (b)**).



Figure 1: Four different flowable composite material representing four different groups



Figure 2: Arranged premolar teeth on typodont



Figure 3: Resin model printed for the fabrication of trays and thermoformed tray with shells

The attachments were placed on the tooth surface by conventional etching with 37% phosphoric acid (Restorite Etching Gel PRIME dental products Pvt. Ltd.) for 25-30 secs, air dried and a layer of primer (ORTHO SOLO Universal

Bonding Primer) was applied. The composite was placed one in each quadrant and cured.

Evaluation of fluorescence of the adhesive was done by exposing the dental arches with attachments to the UV Light Emitting Diode (LED 405±10nm wavelength SUNSHINE SS-003 UV LAMP) and photographs were taken by a digital camera (SONY CORP). Macro lens of 90mm (Da Vincillan 7-D1, 1930 Zaventem, Belgium UK FE 2.8/90) ISO 5000 under standardised condition, under same room light and same surrounding. The camera was stabilised with the help of tripod (Photron STEDY PRO 750).

The Colour Picker tool of the software (Adobe Photoshop Version CC 2017) was used to analyse the differences in colour saturation between the areas of adhesive and teeth. The colours were picked from centre of adhesive area and tooth surface (**Figure 4**).

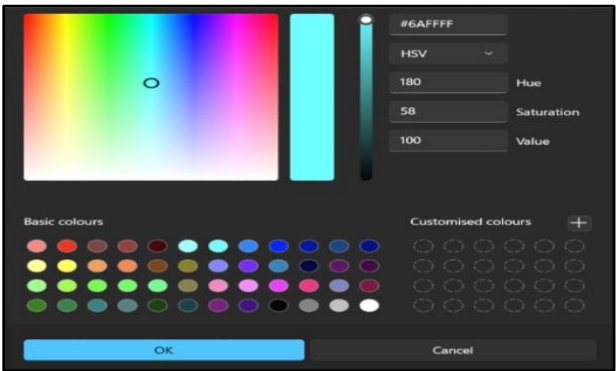


Figure 4: Colour picker tool for evaluation of colour saturation



Figure 5: Differences in colour of resin and tooth surface seen in photographs

The adhesive was removed using a tungsten carbide bur under a fluorescent light emitting diode. It was removed until no no visible adhesive was seen on the tooth surface. After removing the attachments, a post scan was made with intraoral scanner (Dentsply Sirona) and using software (Oracheck 5.0). Superimposition of baseline scan and post scan was done for evaluating the amount of enamel loss and any remnant on tooth surface (**Figure 5**).

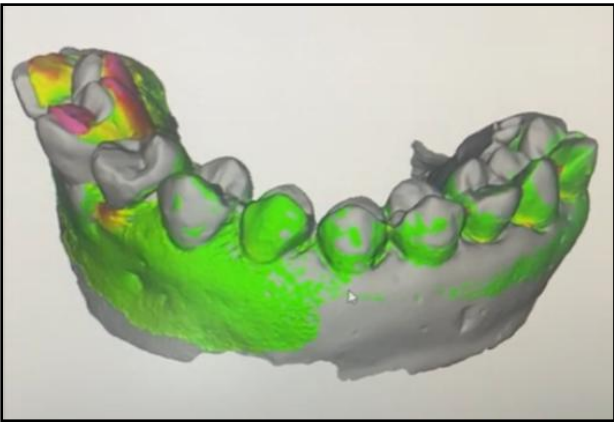


Figure 6: Pre and post scans superimposition

Data were entered into the excel sheet. Data were analysed using SPSS (Statistical Package for Social Sciences) 25.0 version. Data were analysed for probability distribution using Shapiro-wilk test and was found to be normally distributed. Descriptive statistics were performed. Inter-group comparison was done using One-way ANOVA, followed by post hoc analysis, if needed. P-value<.05 was considered statistically significant.

3. Results

Adhesive colour saturation was highest in Group 4 [98.00 ± 0.816], followed by Group 1 [95.00 ± 0.816], followed by Group 2 [94.5 ± 1.914], followed by Group 3 [52.50 ± 4.509]. Adhesive colour saturation in Group 3 was significantly lower compared to the other groups (p-value<.05). The difference between the groups 1, 2, and 4 was statistically insignificant (p-value >.05).

Difference in tooth colour saturation and adhesive colour saturation was highest in Group 3 [26.00 ± 3.162], followed by Group 1 [17.00 ± 1.414], followed by Group 2 [15.50 ± 5.259], followed by Group 4 [4.25 ± 0.349]. The difference in tooth saturation and adhesive saturation in Group 4 was minimum compared to other groups (p-value<.05). The difference between groups 1, 2, and 3 was statistically insignificant (p-value >.05) (**Table 1**) (**Figure 7**)

Table 1: Inter-group comparison of difference in tooth saturation and adhesive saturation.

Groups	Mean $\pm$ standard deviation	f-value	p-value
Group 1	17.00 $\pm$ 1.414	21.751	<.001*
Group 2	15.50 $\pm$ 5.259		
Group 3	26.00 $\pm$ 3.162		
Group 4	4.25 $\pm$ 0.349		

One-way ANOVA. *p-value<.05 was considered statistically significant.

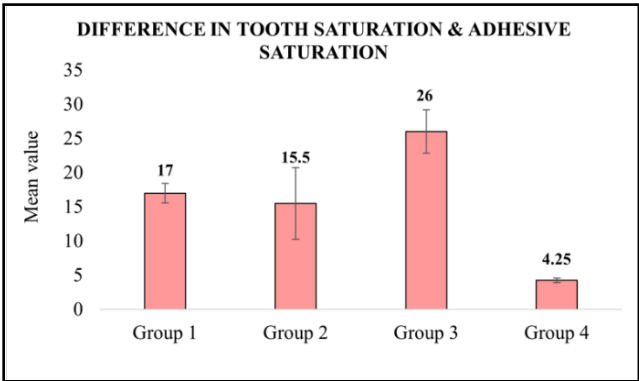


Figure 7: Difference in tooth colour saturation and adhesive saturation.

The enamel loss was highest in Group 4 [1.35 ± 0.460], followed by Group 1 [0.29 ± 0.017], followed by Group 2 [0.27 ± 0.044], followed by Group 3 [0.09 ± 0.015]. The enamel loss in Group 4 was highest compared to the other groups (p-value<.05). The difference between the groups 1, 2, and 3 was statistically insignificant (p-value >.05). (**Table 2**) (**Figure 8**)

The residual composite was highest in Group 4 [1.35 ± 0.460], followed by Group 1 [0.29 ± 0.017], followed by Group 2 [0.27 ± 0.044], followed by Group 3 [0.09 ± 0.015]. The amount of residual composite in Group 4 was significantly greater than that in other groups (p-value<.05). The difference between the groups 1, 2, and 3 was statistically insignificant (p-value >.05).

Table 2: Inter-group comparison of enamel loss.

Groups	Mean $\pm$ standard deviation	f-value	p-value
Group 1	0.29 $\pm$ 0.017	24.485	<.001*
Group 2	0.27 $\pm$ 0.044		
Group 3	0.09 $\pm$ 0.015		
Group 4	1.35 $\pm$ 0.460		

One-way ANOVA. *p-value<.05 was considered statistically significant.

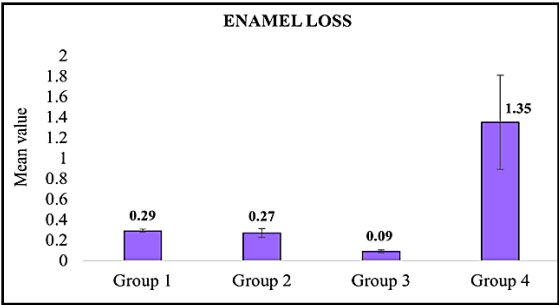


Figure 8: Enamel loss.

4. Discussion

The rise in orthodontic patients has driven a growing demand for aesthetic and comfortable alternatives to traditional braces. Clear aligners, which meet these needs, have seen rapid advancements in materials and production techniques. These innovations have expanded the range and complexity of cases treatable with aligners. Clear aligners offer a discreet and comfortable treatment option, with improved oral hygiene, less discomfort than fixed braces, reduce the frequency and length of appointments, and minimize the need for emergency visits.¹¹ Additionally, these aligners now are used to manage Obstructive sleep apnoea.

The biomechanics of clear aligners depend on custom-made trays to move the teeth to their desired positions. The trays were fabricated using flexible materials and are engineered for delivering precise forces which are required for effective tooth movement. Attachment devices are frequently used for specific type of tooth movements and to ensure proper aligner retention.⁴

In Clear Aligner Therapy, attachments are adhered to the enamel. Once the treatment is completed, a challenge that arises is safely removing the attachments and any residual resin without causing damage to the enamel. Removing even a small layer of enamel can make it more vulnerable to organic acids in the mouth potentially increasing the risk of enamel demineralization and white spot lesions.² However, this meticulous approach may leave some adhesive behind, potentially leading to plaque retentive areas that promote biofilm accumulation, which may result in decalcification and caries and ageing adhesive remnants can discolour leading to patient dissatisfaction.¹²

A more effective approach for removing the resin is by using low speed handpiece with 12-bladed tungsten carbide with adequate air cooling. The remaining enamel surface and residual can be refined and polished using graded polishing discs and ceramic wheels.¹³

The fluorescence-aided identification technique (FIT) is an effective approach for distinguishing adhesives from tooth enamel by utilizing a blue light illumination source as studied by Meller C et al¹⁴ in their study. This technique takes advantage of the differences in fluorescence behaviour between composite materials and enamel surface, typically observed within a wavelength range of 405 ± 10 nm.

Meller C and Klein C¹⁵ conducted a study in which comparison of shades of different composites was done based on their fluorescence and significant differences were seen among all the groups. Using illumination sources within the wavelength range of 405 ± 10 nm simplifies the visual differentiation between natural tooth structure and colour-matched metameric composites. FIT enables quick and accurate detection of tooth-coloured composite restorations. Additionally, it aids in the safe removal of orthodontic

brackets and also for removing trauma splints, reducing the risk of iatrogenic enamel surface damage.¹⁶

Motohiro UO et al.¹⁷ conducted a study to identify presence of rare earth oxides in adhesives. Dettwiler C et al¹⁶ performed a study to compare the fluorescent aided removal of adhesive and the conventional method of adhesive removal and concluded that in comparison to the conventional technique, adhesive removal with fluorescent identification technique is faster, generated less tooth surface loss and minimum residual adhesive. Leontiev W. et al¹⁸ in his study concluded that the FIT technique enhanced the identification and complete removal of resin, while also promoting greater tooth preservation. Additionally, composite removal using this technique is less time-consuming compared to other methods.¹⁶

For our study, 84 extracted premolar teeth were taken and arranged in form of upper and lower arch on typodont. Digital scans were made of the arranged premolars for the comparison of pre and post enamel loss and residual adhesive. Another scan was made and a STL file was created of the arranged premolars for the fabrication of aligner trays. The shell size was designed on each tooth of 2x2 size and a resin model was prepared and later aligner trays were fabricated.

Four commonly used flowable composites were taken for the study. They were categorised into four groups – Group A- Tetric N flowTM (Ivoclar Vivadent), Group B- Polofil NHT FlowTM (VOCO GmBH), Group C- G-aenial universal flowTM (GC America), Group D- Filtek Supreme ultra flowableTM (3M ESPE). Conventional etching, air drying and application of primer was done and attachments were bonded on tooth surface, one adhesive into each quadrant.

After attachments were placed, evaluation of fluorescence of the adhesives was done with the help of a Light Emitting Diode (LED) of blue light and wavelength of 405 ± 10 nm. Under standardised conditions, the light was exposed to each quadrant and photographs were taken with a digital camera. The photographs were compared for the difference in colour saturation of the teeth and adhesive using Colour Picker tool, relatable to a study performed by Brokos I et al¹⁹ where fluorescence of adhesives was evaluated by photographic method.

Hirata R et al²⁰ conducted a study to evaluate fluorescence intensity (FI), where UV light was exposed to the samples, and ten photographs were taken for each group. Each sample was then analyzed digitally. The results indicated that the fluorescence of composites was influenced by composition of the fillers and organic matrix. In our study we have compared the fluorescence of 4 commonly used adhesives based on their fluorescence on the basis of digital photographs. *The colour saturation was maximumt in group 4*, followed by group 1, group 2 and lastly, group 3. The

differences in the colour saturation of the adhesive and enamel surface were seen to be maximum in group 3.

Meller C Scott T²¹ conducted a study where using the FIT technique, the adhesives were clearly verified and quantified. In our study, the adhesive was removed by a tungsten carbide bur under fluorescent Light Emitting diode (405±10nm). After the residual removal under naked eyes until no visible adhesive was seen, a post scan of the enamel surface was made with the scanner. Superimposition of the pre and post scans were made with the help of Omnicam software. *The enamel loss was highest in group 4*, as the difference in colour saturation of adhesive and tooth surface was minimum in group 4.

Olszowsk et al²², Ryf S et al²³ conducted a study which showed that under conventional method of adhesive removal, significant amount of enamel loss and remaining adhesive was seen. In our study the visibility of group 4 was minimum among all the four groups, thus *the adhesive remaining was also maximum in group 4*, followed by group 1, group 2 and finally group 3.

Debonding is equally important as bonding method. The enamel surface has to be brought back to its original form after the treatment to avoid any retentive areas, plaque formation, discoloration and demineralisation. The most commonly used method today is the tungsten carbide bur. Our study focused on understanding the accuracy of fluorescence aided identification technique which shows differences in the fluorescence of the adhesives based on their compositions.²⁴ Thus, more research is needed to study the composition of various adhesives as they are not clearly described by the manufacturers. Also, our study does not take into consideration the fluorescence behaviour of the adhesives based on the viscosity and there is need for more studies on the same.

5. Conclusions

The difference in the fluorescence behaviour of four different flowable composites was observed.

1. G aenial universal flowTM showed maximum differences in colour saturation of adhesive and tooth surface and minimum enamel loss and residual adhesive.
2. Tetric N flowTM, and group 2, Polofil NHT FlowTM showed a significant fluorescence and comparatively less enamel loss and residual adhesive.
3. Filtek Supreme ultra flowableTM does not exhibit fluorescence, thus differentiation between the adhesive and tooth surface was difficult which leads to significant enamel loss and residual adhesive after removal of the composites.

4. The G-aenial universal flowTM is highly recommended for placing the attachments in clear aligner therapy.

6. Source of Funding

None.

7. Conflict of Interest

None.

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