Original Article

Evaluation of a Fluorescence-aided Identification Technique (FIT) to assist clean-up after orthodontic bracket debonding

Oliver Stadler[a]; Christian Dettwiler[b]; Christian Meller[c]; Michel Dalstra[d]; Carlalberta Verna[e]; Thomas Connert[f]

ABSTRACT

Objectives: To compare a fluorescence-aided identification technique (FIT) with a conventional light source (CLS) for removing composite during debonding of brackets with respect to time needed, composite remnants, and tooth substance loss.

Materials and Methods: Twelve maxillary models with 10 bovine teeth each were digitally surface-scanned and metal brackets were bonded on each tooth with Opal Seal and Opal Bond. Two operators: an experienced orthodontist (A) and an undergraduate student (B) received six models each and were asked to remove the composite remnants with a tungsten carbide bur and Sof-Lex discs by both a conventional light source (CLS group, $n = 3$), and fluorescent inducing light (FIT group, $n = 3$). The time taken was recorded, and a postoperative scan was digitally superimposed on the preoperative scan to quantify number of teeth with composite remnants and volume and thickness of enamel loss and composite remnants. Chi-square test and independent *t*-tests were performed to compare methods with a significance level of 5%.

Results: Compared to CLS, both operators needed significantly less time when using the FIT method and degree of enamel loss, height, and volume of composite remnants and total remaining composite remnants were significantly reduced. By FIT, the volume of enamel loss was significantly reduced for operator A only. Operator B removed the same enamel volume with either method.

Conclusions: Cleanup after orthodontic debonding with the FIT was superior regarding time needed and removal of composite remnants. Total enamel loss reduction was operator-dependent. (*Angle Orthod.* 2019;89:876–882.)

KEY WORDS: Bracket debonding; Fluorescence-aided identification technique; Composite resin detection; 3D evaluation

INTRODUCTION

After orthodontic treatment, the enamel surface should be returned to its original condition as close as possible without any composite remnants and without damaging the tooth surface.[1] So far, no consensus exists as to the most efficient technique to remove composite remnants after bracket debonding.[2] Despite many different approaches used in daily practice, the tungsten bur remains the most preferred tool to remove composite remnants.[3,4] Tungsten

The first two authors contributed equally to this work.

[a] Resident, Department of Orthodontics and Pediatric Dentistry, UZB, University Center for Dental Medicine, University of Basel, Basel, Switzerland.

[b] Resident, Department of Periodontology, Endodontology and Cardiology, UZB, University Center for Dental Medicine, University of Basel, Basel, Switzerland.

[c] Associate Professor, Department of Restorative Dentistry, Periodontology, Endodontology and Pediatric Dentistry, School of Dental Medicine, Eberhard Karls University, Tübingen, Germany.

[d] Associate Professor, Department of Orthodontics and Pediatric Dentistry, UZB, University Center for Dental Medicine, University of Basel, Basel, Switzerland.

[e] Professor and Head, Department of Orthodontics and Pediatric Dentistry, UZB, University Center for Dental Medicine, University of Basel, Basel, Switzerland.

[f] Assistant Professor, Department of Periodontology, Endodontology and Cariology, UZB, University Center for Dental Medicine, University of Basel, Basel, Switzerland.

Corresponding author: Dr Carlalberta Verna, Department of Orthodontics and Pediatric Dentistry, UZB, University Center for Dental Medicine, University of Basel, Hebelstrasse 3, 4056 Basel, Switzerland
(e-mail: carlalberta.verna@unibas.ch)

Accepted: April 2019. Submitted: October 2018.
Published Online: June 17, 2019

carbide burs are effective in removing composite remnants but result in a rough enamel surface. Therefore, enamel polishing is required to avoid bacterial adhesion.[5] This is recommended to be performed with Sof-Lex discs (Sof-Lex,3M/ESPE, St. Paul, Minnesota, USA).[2] Although the ideal procedure for removing composite has been the subject of several investigations, less effort has gone into establishing a technique that facilitates the removal of composite remnants.[6–8]

The fluorescence properties of luminescent chemicals and tooth structures are different under a wavelength of 405 nm. Therefore, fluorescence can be a good tool to use as a noninvasive method for detecting composites.[9–12] Recently, this method has been used to assess the effectiveness of composite remnant removal after orthodontic debonding.[6–8] However, the volumetric assessment of composite remnants and enamel loss after debonding as well as the time needed for removal under fluorescent light has not been investigated. The aims of this in vitro study were to evaluate the amount of composite remnants, tooth substance loss, and the time needed for the removal procedure using a fluorescence-aided identification technique (FIT) compared with a conventional light source (CLS).

MATERIALS AND METHODS

One hundred and twenty permanent bovine incisors were extracted, cleaned, and stored in 0.5% chloramine-T solution at room temperature until further processing. To the naked eye, these teeth had an intact surface without any staining, demineralization, caries, enamel cracks, or fractures. Twelve upper dental arches were produced as follows: Ten teeth, ranging from tooth 15 to 25, were mounted on a wax plate with interdental contacts mimicking a maxillary dental arch, interlocked with hot-setting glue, and embedded in hot polymer (ProBase, Ivoclar Vivadent AG, Schaan, Liechtenstein). Teeth were selected and assembled according to the size of the buccal surface to produce a harmonious model. Size of the buccal surface had to be at least double the size of the corresponding bracket to provide enough unaltered surface for subsequent superimposition of the optical scans. The models were randomized into two groups: FIT group (FIT; $n = 6$) and conventional light source group (CLS; $n = 6$). A digital 3D surface scan (CEREC Omnicam, Software SW 4.5,1 Dentsply Sirona, York PA, USA) was performed from the labial, covering the area from tooth 15 to 25 on every model from both groups.

After cleaning with rubber cups using nonfluoridated and oil-free pumice and water for 10 seconds, each tooth was bonded with a conventional bracket (Victory Series, 3M, St. Paul, Minn, USA) by etching the middle third of the crown with 35% phosphoric acid (Opal Etch, Ultradent, South Jordan, Utah, USA) for 60 seconds using a silicon pattern with holes of 5 mm diameter. Then, the acid was rinsed with water for 60 seconds, and the tooth air-dried for 10 seconds. Afterward, the primer and sealant (Opal Seal, Ultradent) was applied and light-cured for 5 seconds (Bluephase 20i, Ivoclar Vivadent AG, Schaan, Lichtenstein). Opal Bond (Ultradent) was applied on the brackets and, once firmly placed and the excess removed, light-cured for 20 seconds mesial and distal of each bracket as suggested by the manufacturer. The prepared models were stored in water for approximately one day until the debonding procedure. To mimic the clinical debonding situation, the models were mounted in a dental mannequin (Frasaco GmbH, Tettnang, Germany), which was permanently fixed to a dental chair (Teneo, Dentsply Sirona, York, Pa, USA).

Two blinded right-handed operators were recruited for the debonding procedure: an experienced orthodontist (A) and an undergraduate student in the fifth year (B). The Ishihara test was performed to exclude color blindness and color weakness. They were instructed to remove the brackets with a bracket-removing plier (678-220L, Hu-Friedy, Chicago, Ill, USA) and all of the composite remnants with a six-blade tungsten carbide bur (H23RA, Gebr. Brasseler GmbH, Lemgo, Germany) mounted in a low-speed contra-angle handpiece (KaVo Master Series, Biberach, Germany) by applying water cooling first and air cooling second. Afterward, the enamel surface was polished with multistep Sof-Lex discs (coarse, medium, fine, super fine; Sof-Lex, 3M) using air cooling. For each model, a new tungsten carbide bur and Sof-Lex discs were used. The operators were instructed to clean the enamel surface until no visible composite remnants could be detected. Magnification was not allowed and, for detection, the operators used dental mirrors, probes and the multifunctional syringe only.

Each operator prepared three of the six models under illumination of the operating lamp (LEDview, Sirona, Bensheim, Germany) of the dental chair (CLS group), and the other three models (FIT group) by using a prototype fluorescence inducing ($\lambda = 405 \pm 7$ nm) headlamp (Karl Storz GmbH & Co. KG, Tuttlingen, Germany). A postoperative optical three-dimensional scan was performed of each model (Figure 1). A digital stopwatch was used to record the time (seconds) from start of composite remnant removal to the end of polishing.

The best-fit method was used to superimpose the pre- and postoperative scans through dedicated superimposition software (OraCheck, Version

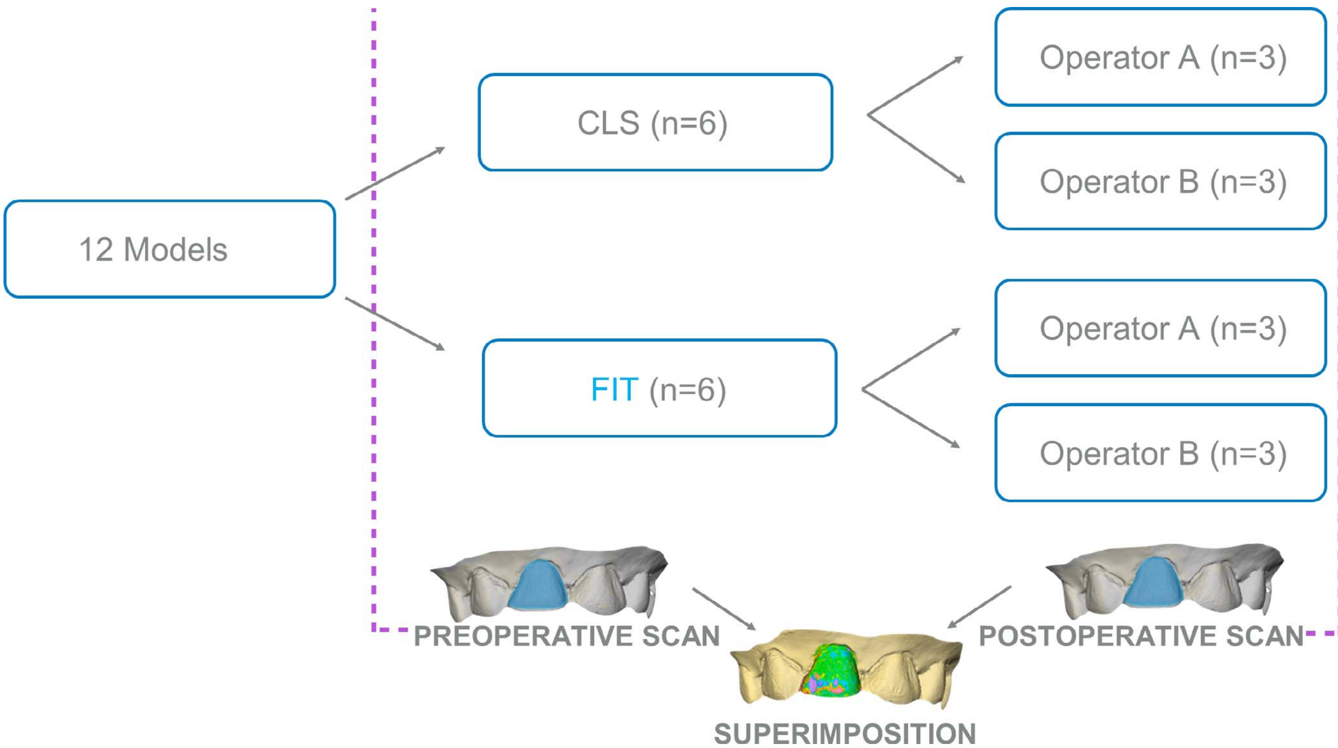

Figure 1. Study flow chart.

2.13.8676, Cyfex AG, Zurich, Switzerland). The unaltered part of the incisal, buccal, and oral surfaces were used as reference points.[12,13] Each tooth surface was superimposed separately and the differences in the distances between any point of the pre-and postoperative scans were identified by color-coding (Figure 2) to the nearest 0.01 mm. All surfaces were analyzed independently by two examiners once. The differences between these two measurements were used to determine the interexaminer variation. The following parameters were measured:

- The number of teeth with composite remnants
- Composite remnant height: the largest perpendicular distance between the tooth and the remnant surface in µm with the "cursor-distance" tool
- Composite remnant volume: the volume of remaining composite in mm^3 with the "volume analysis" tool
- Defect depth: the largest perpendicular distance between the tooth and the defect surface in µm with the "cursor-distance" tool
- Defect volume: the volume of the enamel defect in mm^3 with the "volume analysis" tool
- The time required for composite remnant removal

Statistics

The distributions of the number of teeth with composite remnants for the two techniques and the two operators were assessed with a chi-square test. Statistical significance was set at $P = .05$. For each continuous variable, the mean value, standard deviation and the 95% confidence interval were calculated. Interexaminer variation was calculated using the Dahlberg formula (error of method $= \sqrt{\frac{\sum_{i=1}^{n}(d_{i,1}-d_{i,2})^2}{2n}}$). Normality of the data, a requirement for the independent-samples *t*-test, was assessed and confirmed by Q-Q-Plots. Following the Levene's test for equality of variance, an independent-samples *t*-test was performed to assess significant differences between the two methods and the two operators. The level of significance was set to $P = .05$. The data were analyzed with SPSS, version 23 (IBM Corporation, Armonk, NY, USA).

RESULTS

For each continuous variable, the interexaminer variation was smaller than the standard deviation of either the first or second sets of measurements, meaning that the systematic error was small enough to have no clinical relevance (Table 1). The chi-square statistics revealed no significant difference between Operator A and B regarding the percentage of teeth with composite remnants. Both operators left significantly less teeth with composite remnants with FIT compared with CLS (Figure 3).

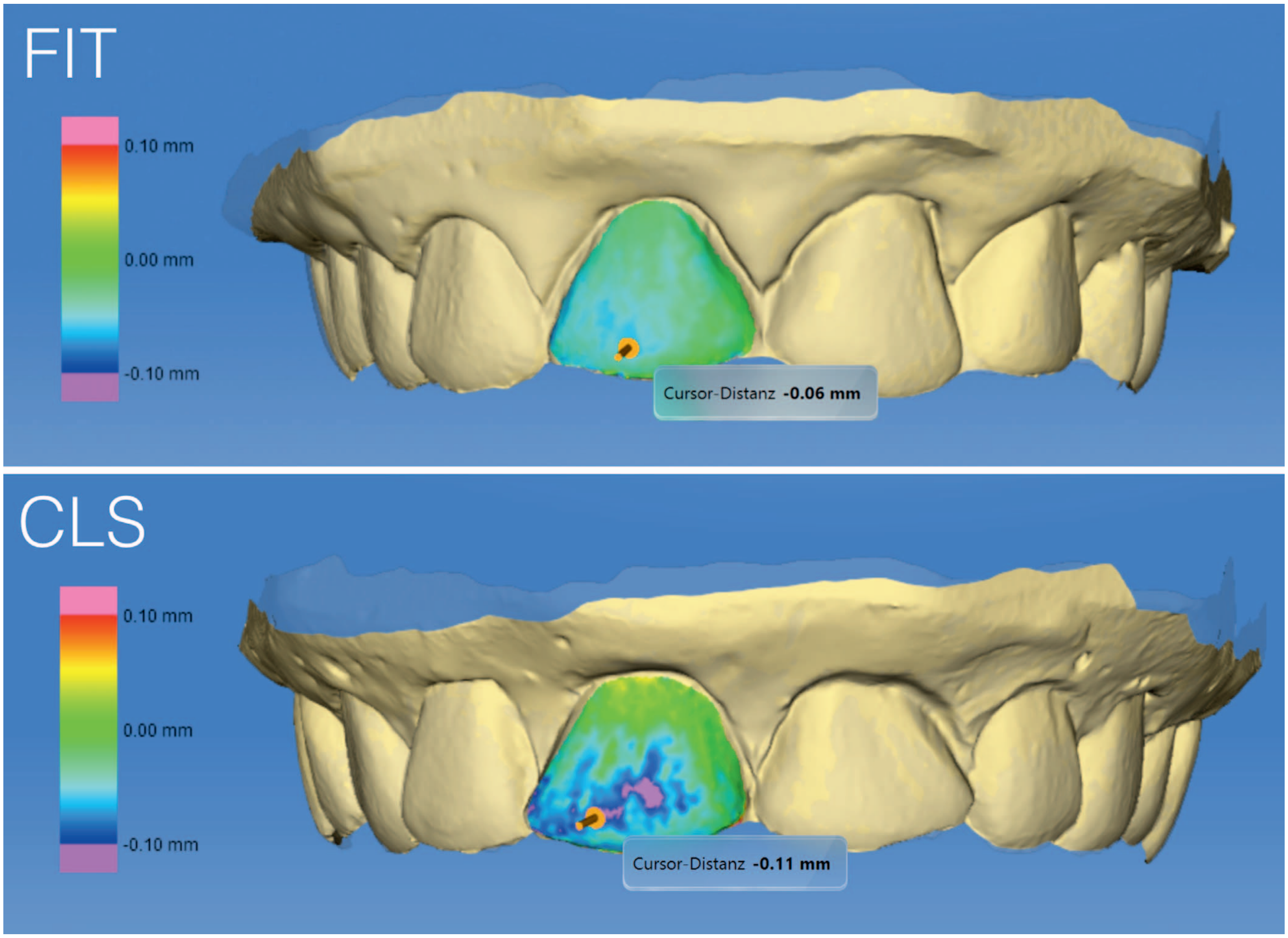

Figure 2. Superimposed 3D scans after composite removal using FIT (Top) and CLS (Bottom). Green represents unchanged areas; substance loss is indicated by blue and violet color, excess material by yellow, red, and pink. Highest peak of composite remnant and deepest enamel defect was assessed by the "cursor-distance" tool.

Height and volume of the composite remnants were significantly higher in the CLS group than in the FIT group, regardless of the operator (Table 2). Both operators produced significantly larger defect depths in the CLS group than in the FIT group (Table 2). The defect volume was significantly smaller in the FIT group than in the CLS group for operator A, but not for operator B (Table 2). Both operators were significantly faster when the removal was performed with FIT (Figure 4). Operator A was significantly faster and left more composite volume than B by using CLS (Figure 4, Table 2). By the FIT method, operator A generated thinner and smaller defects than operator B (Table 2).

DISCUSSION

The present study showed that the FIT was superior to the conventional light technique in amount of composite removed, avoiding enamel defect generation, and time required for clean-up procedures. To simulate a clinical setting and the related operational limitations due to patient's head and teeth position, full arch models were mounted in a dental mannequin. The bovine teeth used have been shown to be an acceptable substitute for human teeth for bonding and polishing tests.[14,15] The collection of human teeth with the same quality regarding the age and storage time without any tooth decay is often difficult.[16] The

Table 1. Interexaminer Variation: Results from the Double Measurements

	Remnant Height, mm	Remnant Volume, mm^3	Defect Depth, mm	Defect Volume, mm^3
Error of the method	0.004	0.007	0.003	0.023
Minimum standard deviation	0.04	0.104	0.036	0.426
Pearson coefficient	0.9795	0.9923	0.9831	0.995

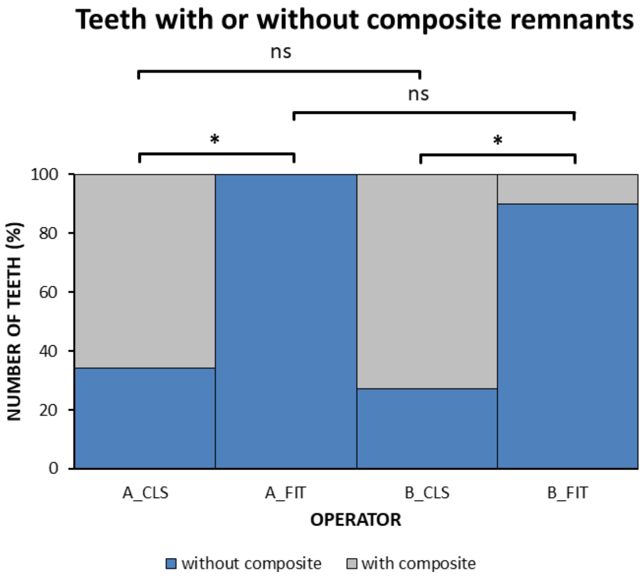

Figure 3. Percentage of teeth with or without composite remnants for the two operators (A and B) and the two techniques (CLS and FIT). Statistically significant differences in the distributions are given by * $P = .05$.

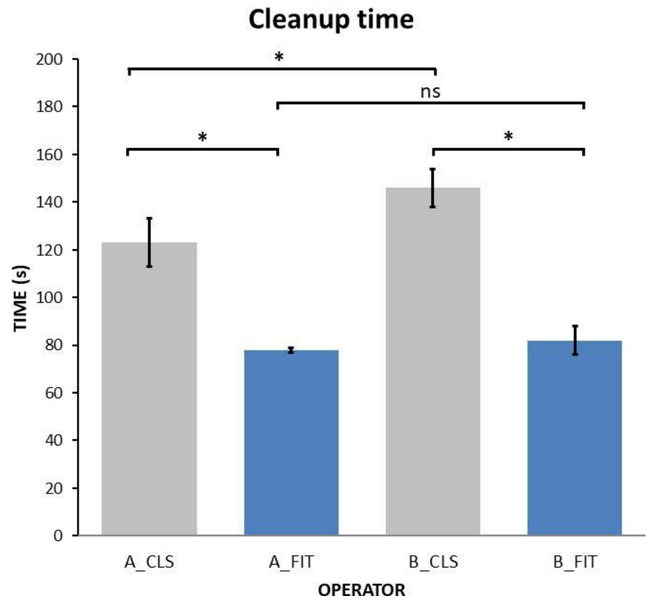

Figure 4. Graphical representation of the average cleanup time for the surface of a single tooth for the two operators (A and B) and the two techniques (CLS and FIT). The error bars represent the standard deviations. Asterisks indicate statistical differences between groups: * $P = .05$.

large and flat tooth surfaces of the bovine incisor teeth provided enough unaltered surface, which was used as a reference for the 3D superimposition. The bovine teeth of this study were in an identical development stage at the time of collection. By means of a standardized manner of cleaning, disinfection, and storage time, the comparability could be guaranteed.

Intraoral scanning was chosen, since it is a cost-effective, quick, and easily applicable measuring tool for clinical investigations with a high reliability.[12,17] The direct 3D digitalization reduced the risk of imprecision due to the elimination of intermediate steps required by the scanning of plaster casts.[18] Since scanning precision improves from full arch to quadrant and to single tooth,[19–21] each tooth was superimposed separately.

The number of teeth with composite remnants was relatively high in this study (CLS: A: 66% and B: 73%) compared with the study by Ryf et al. (27%).[1] Polishing systems with good composite polishing properties may foster more composite remnants due to the lustrous surface that can be achieved with them.[1] Therefore, the good polishing properties of the Sof-Lex discs[22] may have resulted in more teeth showing composite remnants. In this study, the height of composite remnants ranged from 0 to 57 μm and the composite remnant volumes from 0 to 0.15 mm³. The study of Ryf et al.[1] reported an average height of 229.2 μm, which was considerably more, and a mean composite volume of 0.22 mm³. The polishing with the Sof-Lex discs may have left a thin, but larger, area with composite remnants on the teeth, leading to a comparable result for composite volume. Further discrepancies may not only be explained by the different experimental conditions, but also by the different methods of measurement and calculation.

Table 2. Results for Operator A and B for Both Methods (CLS or FIT): Surface Changes (μm) and Volume Changes (mm³), Standard Deviation, Minimum and Maximum and *P* Values[a]

	Operator															
	A							B							A vs B	
	CLS			FIT			CLS vs FIT	CLS			FIT			CLS vs FIT	CLS	FIT
Group	Mean	SD	Range	Mean	SD	Range	*P* Value	Mean	SD	Range	Mean	SD	Range	*P* Value	*P* Value	*P* Value
Composite remnants																
Height, μm	57	44	0–120	0	0	0	<.001	53	40	0–120	4	12	0–50	<.001	.749	.082
Volume, mm³	0.15	0.14	0–0.53	0	0	0	<.001	0.07	0.08	0–0.33	0.009	0.03	0–0.22	<.001	.018	.204
Enamel defects																
Depth, μm	81	24	40–130	32	37	<10–90	<.001	90	35	40–190	67	20	40–130	.002	.242	<.001
Volume, mm³	0.42	0.32	0.07–1.27	0.17	0.21	0–0.71	<.001	0.61	0.57	0.07–2.36	0.61	0.37	0.24–1.62	.975	.113	<.001

[a] CLS indicates conventional light source; FIT, fluorescence-aided identification technique.

The phosphoric acid etching technique leads to bonding infiltration between 10–20 μm in the enamel of human teeth[23] and 8.7 μm in bovine teeth.[6] Due to infiltration, complete removal of the composite remnants is never possible without damaging the enamel surface.[2,23] By conventional light, the primer and sealant agent may still remain on the teeth even though, clinically, the surface might look clean.[24] The resin infiltrated enamel could be responsible for color changes of the enamel in the long term.[25] Due to the FIT method, this infiltrated enamel layer becomes visible, which will then be removed during the clean-up process. This can lead to an increased enamel loss of up to 60 μm with a tungsten carbide bur.[6]

Enamel scratches should be avoided as much as possible[26] since they enhance bacterial adhesion[5] and cannot be eliminated by polishing.[27,28] These enamel alterations of bracket debonding and adhesive removal affect the optical properties of the enamel surface.[25] The FIT method could reduce the depth of enamel defects.

Improper handling of the tungsten carbide bur at the line angle and cervical areas can lead to visible grooves[29] and the pressure against the enamel is operator-dependent.[30] In this study, operator B produced flatter, but a similar amount of enamel defects with both methods compared to the more experienced orthodontist who, to a significant degree, produced flatter and smaller enamel defects using FIT. This difference may have been due to an improper use of the instruments by the less experienced operator.

Examination of the dry enamel by conventional light is crucial for detecting surface irregularities[31] and, therefore, helps in the detection of composite remnants.[24] The previously reported high sensitivity of the FIT method[12] allowed the detection of even small composite remnants in hard to find areas during clean-up, for example in grooves or pits.[28,32] Therefore, the FIT allows the use of rotating instruments by water cooling, thus limiting a potential temperature increase that may damage the pulp with temperature increases of the pulp observed during dry clean-up.[33]

Any time reduction is essential for the clinician[1] and might also increase patient comfort. In the present study, the mean time required for one tooth clean-up by CLS (A: 123 seconds, B: 146 seconds) was slightly increased compared with the studies of Krell[34] a (113 seconds) and Vidor[35] (79 seconds) using the same method. The FIT method reduced the time significantly to 78 seconds (A) and 82 seconds (B). The increased speed of the FIT method during clean-up, in addition to the high detection sensitivity and specificity, is another advantage of the technique.[12]

Limitations

The in vitro information provided by this study may not directly reflect the in vivo situation. It should be emphasized that further clinical studies are needed to support these results.

CONCLUSIONS

- The FIT method improves detection and removal of composite remnants.
- The clean-up is faster with FIT than with CLS.
- The damage to the enamel is operator-dependent even with the FIT method.

ACKNOWLEDGMENTS

The authors are indebted to 3M, Germany, for the brackets and to Orthoby, Switzerland, for the bonding material. The authors thank the Swiss Dental Association for providing the research grant for this work.

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