Quantitative Light-induced Fluorescence-Digital as an oral hygiene evaluation tool to assess plaque accumulation and enamel demineralization in orthodontics

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ABSTRACT
Objective: To assess the use of Quantitative Light-induced Fluorescence-Digital as an oral hygiene evaluation tool during orthodontic treatment.

Materials and Methods: In this prospective, randomized clinical trial, 33 patients undergoing fixed orthodontic appliance treatment were randomly allocated to receive oral hygiene reinforcement at four consecutive appointments using either white light (WL) or Quantitative Light-induced Fluorescence-Digital (QLF) images, taken with a device, as visual aids. Oral hygiene was recorded assessing the QLF images for demineralization, by fluorescence loss (ΔF), and plaque coverage (ΔR30). A debriefing questionnaire ascertained patient perspectives.

Results: There were no significant differences in demineralization (P = .56) or plaque accumulation (P = .82) between the WL and QLF groups from T0 to T4. There was no significant reduction in demineralization, ΔF, in the WL, or the QLF group from T0–T4 (P > .05); however, there was a significant reduction in ΔR30 plaque scores (P < .05). All the participants found being shown the images helpful, with 100% of the QLF group reflecting that it would be useful to have oral hygiene reinforcement for the full duration of treatment compared with 81% of the WL group (OR 2.3; P < .05).

Conclusions: Quantitative Light-induced Fluorescence-Digital can be used to detect and monitor demineralization and plaque during orthodontics. Oral hygiene reinforcement at consecutive appointments using WL or QLF images as visual aids is effective in reducing plaque coverage. In terms of clinical benefits, QLF and WL images are of similar effectiveness; however, patients preferred the QLF images. (Angle Orthod. 2016;86:991–997.)

KEY WORDS: Quantitative Light-induced Fluorescence; Oral hygiene reinforcement; Orthodontic treatment; Demineralization; Plaque

INTRODUCTION

In fixed orthodontics, brackets and archwires are significant plaque stagnation sites, so conventional oral hygiene is more difficult. This can lead to demineralization, which may present within 4 weeks of appliance placement.¹ Assessing a patient’s standard of oral hygiene at each visit is part of the routine clinical assessment, and regular oral hygiene reinforcement should be given as required. Direct visual assessment is the most commonly used method of assessing plaque with ordinal indexes, such as Silness and Loe,² enabling quantification. Similarly, demineralization is usually assessed by direct vision, which can be criticized because considerable mineral loss may be sustained before a white mark becomes visible.³

A Quantitative Light-induced Fluorescence-Digital device (Inspektor Research Systems BV, Amsterdam, The Netherlands) combines an SLR camera with light sources and filters to produce Quantitative Light-induced Fluorescence (QLF) and white light (WL) images. The QLF technique is based on the property of enamel to autofluoresce when illuminated by visible light. During demineralization, minerals are replaced by water, resulting in a reduced fluorescence radiance (Figure 1) compared with sound enamel. QLF has been demonstrated to be a reproducible and valid technique, with image analysis providing a measure of the mean percentage fluorescence loss of the lesion, $\Delta F$, based on the amount of mineral loss sustained. In vitro and in vivo studies have demonstrated that QLF is an appropriate technique for longitudinal monitoring of demineralization. Additionally, autofluorescence of bacterial porphyrins enables plaque detection (Figure 2) with a quantitative score, $AR_{30}$, related to the number of pixels covered with red fluorescence. Pretty et al. demonstrated that QLF is a reliable tool for assessing plaque accumulation in vivo.

This study was designed to assess a new method of oral hygiene reinforcement during orthodontic treatment. QLF and WL images were taken and used as visual aids to demonstrate the standard of oral hygiene currently being achieved by patients undergoing treatment. The null hypothesis was that there would be no significant difference in demineralization or plaque accumulation between individuals being shown the QLF or the WL images.

**MATERIALS AND METHODS**

The study was a prospective randomized, clinical trial (RCT) with two parallel groups. The setting was the Orthodontic Department, Royal Liverpool University Dental Hospital, Liverpool, United Kingdom. Ethical approval was obtained from the North West Research Ethics Committee–Liverpool Central (REC reference: 13/NW/0005), and the project was registered with the Royal Liverpool and Broadgreen University Hospital Trust Research and Development Department (REF: 4415). The intervention was in two clinical arms, with oral hygiene reinforcement being provided using either the WL or QLF images as visual aids.

There were no previous studies available on which to base a sample size calculation. The study was subsequently conducted as a pilot study, but a formal sample size calculation was not carried out. A sample size of 30 was chosen, as this would allow estimation of parameters for a sample size calculation to be conducted in future definitive studies.

Consecutive patients attending Liverpool University Dental Hospital for orthodontic treatment conducted by the same clinician were asked to participate. The following inclusion criteria were applied:

- All subjects in good health
- At least 11 years of age
- Undergoing maxillary and mandibular fixed appliance treatment

The following exclusion criteria were applied:

- Significant disabilities that might affect manual dexterity or oral hygiene practice
- Patients who had had antibiotics in the preceding 2 months
- The presence of full coverage restorations
- The presence of visually cavitated lesions

At baseline assessment (T0), the archwires were removed and the device was used to take frontal and buccal images of the maxillary and mandibular dentition when the patient was occluding edge to edge. If required, a prophylaxis was conducted to remove any plaque deposits, and the photographs were repeated to allow an assessment of demineralization.
The QLF images were assessed at least a week later for the presence of demineralization. If there was at least one area of demineralization present, the individual was classed as high risk (HR). If no areas of demineralization were present, the individual was classed as low risk (LR).

The randomization process, which was stratified by demineralization risk, was conducted by an independent statistician. A random number sequence was produced by a computer-generated program. Allocation concealment was with consecutively numbered, sealed, opaque envelopes. At the subsequent routine appointment (T1), the next envelope was opened and allocation was made into one of the two parallel groups. All the patients were treated by one operator.

The first patient enrolled in March 2013 and the last patient completed the study the following November.

The standard of oral hygiene was reassessed at four consecutive routine appointments (T1–T4) at approximately 6-week intervals. Images were taken and the subjects were given oral hygiene reinforcement, focusing on the areas of poorer plaque control or where demineralization was present, using the WL or the QLF images as visual aids. On completion of the study, the participants were given a debriefing questionnaire that focused on their perception of being shown the images.

**Image Analysis**

The QLF images were analyzed by one clinician at least 1 week later. This interval was based on previous studies, which had employed a similar time frame between repeated measurements. A measurement of plaque accumulation on each tooth was graded as $\Delta R_{30}$. For areas of demineralization, an outline was drawn around each lesion with borders on sound enamel and the mean $\Delta F$ was recorded.

**Statistical Analysis**

The data were analyzed using SPSS Version 20.0 software (SPSS Inc, Chicago, Ill). The primary outcome variables were the percentage change in demineralization ($\Delta F$) and plaque accumulation ($\Delta R_{30}$) from T0–T4. As the outcome was measured at tooth level but the randomization was at participant level, multilevel linear regression was used for the analysis to control for the clustering of teeth within participants.

**RESULTS**

A total of 33 patients were recruited. Figure 3 highlights the flow of patients through the trial. The patients were randomly allocated to the WL or QLF groups stratified according to the presence of demineralization at T0. This resulted in 16 being allocated to the WL group and 17 to the QLF group.

**Baseline Data**

There were 21 females and 12 males recruited into the study (Table 1). The median age of the sample was 14.6 years (minimum, 11.0; maximum, 37.4 years). There were no differences between groups at baseline for gender ($P = .90$, chi-square test) or age ($P = .42$, Mann-Whitney U-test). The overall mean number of teeth assessed per participant was 18 (SD, 3.1) with no differences between the two groups ($P = .43$, t-test).

**Demineralization**

The mean percentage change in $\Delta F$ from T0–T4 was $-21.8\%$ and $-13.3\%$ in the QLF and WL groups, respectively (Table 2), with wide 95% confidence intervals ($P > .05$). The test of the fixed effect of the intervention showed no difference between the QLF and WL groups ($P = .56$).
The outcome measure percentage change in ΔF could only be used to assess the HR individuals as those stratified as LR had no detectable demineralization at baseline. To account for this, an analysis was undertaken at a participant level to include all individuals. Assessing the total number of lesions present, we found that, in the HR group, four participants had fewer lesions and seven participants had more. In the LR group, one participant developed a lesion, and the remaining 15 did not develop any lesions. There was a significant difference between the HR and LR groups ($P = .001$, chi-square test), which confirmed the need for the randomization process to have been stratified on the baseline demineralization risk. Overall, there was no difference in change of lesions present between all the QLF and WL participants ($P = .39$, chi-square test). Additionally, subgroup analysis by stratification showed no differences (HR−QLF vs HR−WL, $P = .84$; LR−QLF vs LR−WL, $P = .44$, chi-square test).

**Plaque Accumulation**

The mean percentage change in ΔR30 was −51.0 and −47.3 in the QLF and WL groups, respectively (Table 2). The confidence intervals indicate that the mean reductions noted were significantly lower in both groups at T4 than at T0 ($P < .05$). The test of the fixed effect of the intervention indicated that there was no difference between the groups ($P = .82$).

**Patient Perspective**

The debriefing questionnaire (Table 3) demonstrated that the patients were very positive about being shown the images. All the participants (100%) found it helpful being shown the images. Interestingly, significantly more participants allocated to the QLF group than the WL group thought it would be useful to be
given the oral hygiene reinforcement for the whole duration of treatment, with an OR of 2.3 (95% CI: 1.5–3.5, P < .05).

**DISCUSSION**

This study assessed the Quantitative Light-induced Fluorescence-Digital device as an oral hygiene evaluation tool. There was no improvement in demineralization in either the WL or QLF groups. Additionally, there was no difference between the WL and QLF groups in change in ΔF at the tooth level or in the number of lesions present at the participant level. It is possible that demineralization present at T0 was irreversible, with limited potential for improvement, leading to any intervention having minimal effect. Mattousch et al.\textsuperscript{14} conducted a prospective longitudinal study using Quantitative Light-induced Fluorescence-Digital on 51 patients who had completed fixed orthodontic treatment.\textsuperscript{14} The median ΔF of lesions at debond was 8.5. Overall, in the 2-year period assessed, there was a 39% improvement in the number of lesions. There was a significant improvement in ΔF within the first 6 months; however, no further improvement was achieved after this, suggesting that lesions with median ΔF 8.5 have a potential for improvement, particularly immediately following debond. In this study, the baseline median ΔF was 8.7, indicating that similar findings may have been accomplishable. However, as the participants were undergoing active treatment, there was an increased risk of developing new lesions rather than seeing any improvement. Julien et al.\textsuperscript{15} assessed pre- and post-treatment digital images and found that 23.4% of 885 patients developed at least one lesion during fixed orthodontic treatment.\textsuperscript{15} Thus, the likelihood of gaining improvement in ΔF, as seen in the debond study,\textsuperscript{14} is limited. Hence, it is important to draw attention to the 21 individuals who did not develop any additional lesions throughout the study. One can speculate that the intervention, which resulted in a statistically significant improvement in plaque levels in both groups, facilitated the prevention of further lesions developing.

Another factor that may have led to the lack of any significant changes being noted in demineralization may be that the study was relatively short. An RCT by Eppright et al.,\textsuperscript{16} involving the use of a weekly text message being sent to the parents of patients undergoing orthodontic treatment and a control group who did not receive such a text reminder, found no difference in the prevalence of demineralization between the groups. The authors advised that to accurately assess the development of demineralization with an intervention, longitudinal monitoring should be undertaken for greater than 6 months. In this study, the participants were assessed over five visits (T0–T4), held at 6–8 week intervals. The mean overall length of involvement in the study was 5.4 months (SD 0.5), which might have been insufficient to assess significant differences in the development of new lesions between the QLF and WL groups.

Studies on oral hygiene reinforcement during orthodontics tend to focus on measures of periodontal health, such as bleeding on probing and plaque indexes. A systematic review\textsuperscript{17} found that oral health promotion during fixed orthodontic treatment led to short-term improvements in plaque control or gingival health in four of the six studies. In our study, there were statistically significant reductions in ΔR30 from T0–T4 in both groups, highlighting the benefit of the oral hygiene reinforcement intervention. However,
there were no differences noted between the groups. Marini et al. noted similar findings assessing 60 patients undergoing fixed orthodontic treatment who were randomly allocated to receive repeated oral hygiene instruction and motivational reinforcement at six 4-weekly visits or at a single visit.18 There was a significant reduction in plaque with repeated episodes of oral hygiene reinforcement, highlighting the importance of active reminder systems.

Many oral health promotion techniques have been proposed during orthodontics, including the use of disclosing agents,19 feedback report cards,20 counseling sessions,21 reward systems,20 and weekly text message reminders.16 However, participants’ perspectives of such interventions are infrequently gained. In this study, the participants in both groups expressed positive responses to the oral hygiene reinforcement technique. A significantly greater number of participants in the QLF group than the WL group felt it would be useful to have it for the full duration of treatment, suggesting that these images are more useful. Patients often have difficulty localizing plaque deposits. The WL images are essentially a direct visual assessment, equivalent to assessing one’s self in the mirror; thus, if patients struggle to detect the plaque by direct vision, it is understandable how the QLF images, where plaque is demonstrated as bright red areas, may be advantageous.

A potential confounding factor was the variation in oral hygiene practice as some of the individuals routinely brushed their teeth in the waiting room prior to the appointment. However, by not standardizing this, the study allowed an assessment of everyday oral hygiene control. Additionally, the hygiene products used at home were not controlled, which is in contrast to the RCT by Peng et al., wherein participants were supplied with toothbrushes and toothpaste for standardization purposes.22

An additional limitation was that it was not possible to blind the treating clinician, who provided oral hygiene reinforcement and undertook image analysis. The images were anonymized; however, there is a risk of recall bias. Thus, an appropriate time interval was employed between taking and analyzing the images. There is also a risk of measurement bias as the assessor has to subjectively demarcate the lesion or tooth for QLF analysis. However, strict analytical instructions were abided by, and previous studies have demonstrated high levels of intra- and interexaminer agreement.12

CONCLUSIONS

- QLF images were equally as effective as WL images as oral hygiene reinforcement visual aids.
- There was no improvement in demineralization in either group. However, as the assessment period took place during active fixed appliance treatment, the risk of developing demineralization was ongoing and thus the ability to gain significant improvement may have been limited.
- There was a reduction in plaque coverage in both groups, highlighting the benefit of regular oral hygiene reinforcement using the images. Photographic records are taken frequently to monitor the occlusion; it would be beneficial for these to be used to provide personalized advice.
- More QLF participants felt it would be useful to have oral hygiene reinforcement for the full duration of treatment than WL participants. Thus, from a patient perspective, QLF images may be a more useful aid. It may be advantageous for a Quantitative Light-induced Fluorescence-Digital device to be used instead of a conventional camera, as WL photographs can still be taken, with the additional benefit gained of having access to QLF images.

REFERENCES