

## Fluorescence-Guided Theragnosis in Fixed Orthodontic Therapy: Current Applications and Future Perspectives

Olivia Wilson<sup>1</sup>, Hannah F. Miller<sup>1\*</sup>, Olivia Anderson<sup>1</sup>, Emily Brown<sup>1</sup>, James Johnson<sup>1</sup>, Daniel K. Davis<sup>1</sup>

<sup>1</sup>Department of Preventive and Community Dentistry, School of Dentistry, University of Sydney, Sydney, United Kingdom.

\*E-mail ✉ [hannah.miller@hotmail.com](mailto:hannah.miller@hotmail.com)

Received: 10 February 2023; Revised: 12 April 2023; Accepted: 16 April 2023

### ABSTRACT

Dental biofilm is a major source of bacteria that produce toxins, peptides, lipopolysaccharides, and organic acids, contributing to gingival inflammation and tooth decay. If plaque persists, it can progressively damage surrounding soft and hard tissues. In patients undergoing fixed orthodontic treatment, appliances such as arch-wires, brackets, and elastic modules serve as significant sites for plaque accumulation, complicating oral hygiene maintenance. A major challenge for dentists is the limited ability to fully visualize this biofilm, which hampers effective plaque removal. Currently, visual assessment remains the most common approach for plaque detection, with various indices used to quantify plaque levels; however, these assessments are often inconsistent, subjective, and operator-dependent, leading to variable results. Fluorescence-based methods have emerged as a promising tool for more precise plaque identification and management. Studies suggest that both clinicians and patients find fluorescence useful for monitoring oral hygiene during treatment. This technique allows orthodontists and researchers to detect early demineralization and facilitates efficient removal of orthodontic adhesive cements when used with high-speed burs, offering faster, safer, and less labor-intensive outcomes. The use of fluorescence-enhanced theragnosis enables guided, controlled treatment, providing benefits such as early caries detection, biofilm identification, and improved treatment outcomes through informed selection of resins for esthetic procedures.

**Keywords:** Theragnosis, Biofilm, Orthodontics, Fluorescence

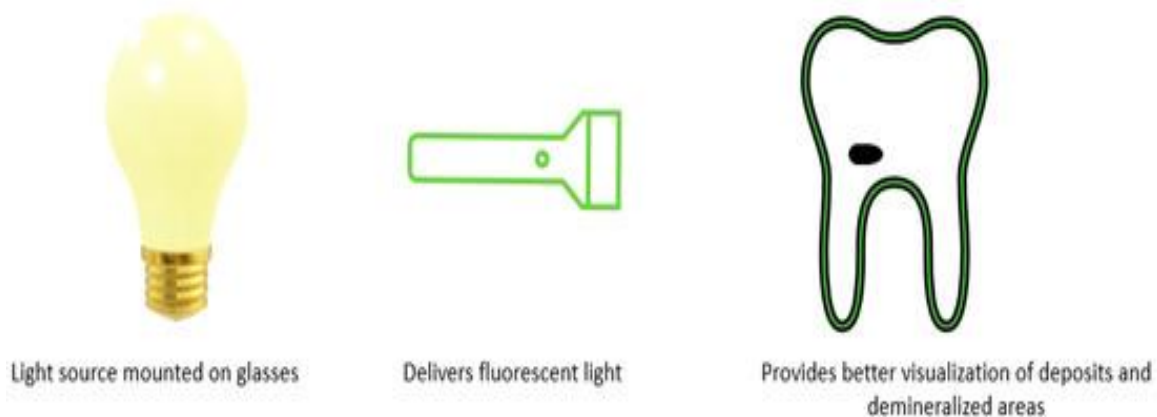
**How to Cite This Article:** Wilson O, Miller HF, Anderson O, Brown E, Johnson J, Davis DK. Fluorescence-Guided Theragnosis in Fixed Orthodontic Therapy: Current Applications and Future Perspectives. *J Orthod Periodontal Biomater Res.* 2023;3(1):52-8. <https://doi.org/10.51847/WiTYoC45Q>

### Introduction

Dental plaque develops as a result of various bacterial species forming an adhesive layer on the tooth surface, which can quickly accumulate and establish colonies that create a biofilm, particularly in interdental spaces and along gingival margins [1, 2]. Once established, this biofilm releases toxins, peptides, lipopolysaccharides, and organic acids, which over time contribute to gingival inflammation and dental caries [3, 4]. Timely removal of this biofilm can restore gingival health without causing damage to soft or hard tissues [5]; however, if allowed to persist, it can progressively harm periodontal structures and lead to enamel caries [6, 7]. Over time, the biofilm may extend subgingivally, promoting the formation of periodontal pockets as the environment becomes increasingly anaerobic and complex [8]. As long as the biofilm remains, it continues to destroy adjacent soft and hard tissues. A key challenge for clinicians is that this biofilm is difficult to visualize completely, limiting the effectiveness of plaque removal. This challenge is intensified in orthodontic patients, where fixed appliances such as brackets and wires complicate plaque monitoring, and clinicians often rely on patients' oral hygiene practices between appointments, assessing plaque primarily through disclosing solutions during follow-ups [9].

In patients undergoing fixed orthodontic therapy, arch-wires, brackets, and elastic modules are well-documented sites of substantial plaque accumulation, which hinders effective oral hygiene [10]. Prolonged plaque retention can result in enamel demineralization even within the typical four-week interval between appointments [10]. During each follow-up, clinicians must evaluate plaque accumulation and emphasize the importance of proper oral hygiene. Visual assessment remains the most widely used approach for plaque detection, and various indices have been validated for quantifying plaque levels [11]. While visual methods are effective for detecting plaque, they are insufficient for identifying subsurface demineralization, which can occur before the appearance of white spot lesions [12]. Research on oral hygiene reinforcement in orthodontic patients has primarily focused on periodontal health, hygiene techniques, and plaque quantification [13], including strategies to improve patient compliance with or without repeated hygiene instructions [14]. The first step in motivating patients is clear visualization and assessment of their oral hygiene status, using approaches such as disclosing agents, reward systems, report cards, and digital reminders [15-18]. However, visual methods are often inconsistent, subjective, and operator-dependent, potentially producing unreliable results, while disclosing agents may stain tissues and compromise esthetics, and patients may disregard reminders or reports.

A non-invasive, objective method for plaque detection and assessment would therefore be highly beneficial in orthodontic care [19]. Fluorescence is one such promising technique (**Figure 1**), in which certain substances, containing fluorophores, absorb light at a shorter wavelength and emit it at a longer wavelength as they transition from higher to lower energy states [20, 21]. Studies have demonstrated that dental plaque fluoresces under 405 nm light even without the use of disclosing agents [22], with older and more cariogenic plaque exhibiting stronger fluorescence than recently formed biofilm [23]. Once fluorescent, plaque can be easily detected using dedicated cameras, facilitating visualization and more effective removal. Beyond plaque detection, fluorescence has proven valuable for identifying oral mucosal changes, early detection of oral cancers [24], and delineating bone-resection margins in surgical cases such as osteonecrosis [25].



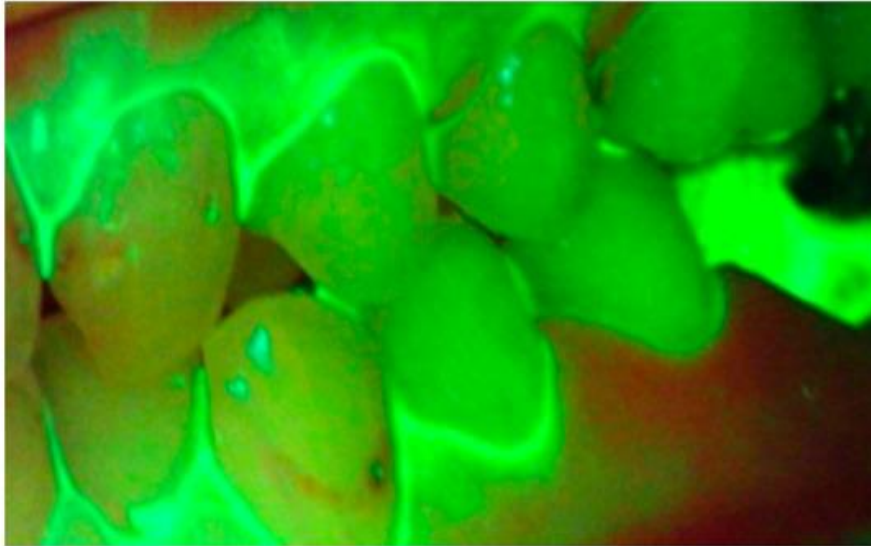
**Figure 1.** Schematic illustration showing how fluorescent light enhances the visualization of deposits and demineralized areas. Pathogenic bacteria within the biofilm produce porphyrins, which, when exposed to specific wavelengths, emit light at characteristic wavelengths. To accurately observe and diagnose bacterial presence, the observer must use specialized filters, and the excitation light must match the intended visualization target's spectral requirements

Fluorescence offers several advantages during fixed orthodontic therapy across different clinical scenarios. This paper aims to review the current literature on fluorescence-enhanced theragnosis and to explore its potential applications and benefits throughout various stages of orthodontic treatment.

#### *Hygiene motivation and monitoring during treatment*

Ineffective, delayed, or incomplete plaque removal is a primary contributor to periodontal issues and dental caries during fixed orthodontic therapy. Providing an efficient preventive solution to detect and eliminate plaque can help avoid additional treatment costs [26, 27]. During active orthodontic treatment, plaque accumulation is often higher because brackets and wires shield it from saliva, mastication, and brushing [28-31]. The difficulty in highlighting plaque in these patients makes it challenging to assess oral hygiene, educate patients, and motivate improvements. Research using fluorescence has demonstrated that both clinicians and patients find this method

particularly helpful for monitoring oral hygiene during treatment [32]. Studies have shown that fluorescence-guided interventions can reduce plaque coverage on brackets, emphasizing the importance of ongoing oral hygiene reinforcement in patients undergoing fixed orthodontic therapy (**Figure 2**). Additionally, images captured under fluorescent light may aid in diagnosis and serve as valuable documentation for patient progress, medico-legal records, and research purposes.



**Figure 2.** Oral hygiene and plaque accumulation status highlighted using fluorescent light

#### *Early demineralization detection*

Demineralization, commonly presenting as white spot lesions, frequently occurs during orthodontic treatment [33, 34]. These lesions not only raise esthetic concerns but also increase the risk of dental caries. Studies have shown that patients undergoing fixed orthodontic therapy experience white spot lesions at twice the rate of individuals without such treatment [35], with incidence further exacerbated by the consumption of sugar-rich foods [35]. Early detection of demineralization allows for timely remineralization, helping to prevent aesthetic compromise or the need for restorative procedures. Fluorescent light provides an indirect method for assessing demineralization by correlating enamel fluorescence intensity with mineral content [36] (**Figure 3**). This approach offers orthodontists and researchers a novel tool to identify early demineralization during treatment.



**Figure 3.** Comparison of intra-oral pictures depicting white spot lesions with and without fluorescent light

#### *Resin cement assessment and white spot lesions after debonding*

Previous studies have demonstrated that fluorescence can effectively identify white spot lesions and residual resin cement following the removal of orthodontic brackets [37]. Teeth bonded with brackets often accumulate plaque and show varying degrees of white spot lesions once treatment is completed and brackets are debonded [38]. After bracket removal, exposure of the affected enamel to saliva and brushing allows these lesions to stabilize, and

remineralization can be facilitated with fluoride-based agents [39]. Fluorescent light has proven highly effective in visualizing white spot lesions, which appear as dark areas in captured images [40].

Although the bonding of orthodontic brackets is well-established, challenges remain in removing residual adhesive composites [41]. Difficulties commonly arise due to limited accessibility, particularly in the molar regions, visualization constraints, and differences in conditioning areas across teeth [42]. Combining fluorescent light with high-speed burs allows for faster, safer, and more efficient removal of orthodontic adhesive cements.

#### *Comparison of various orthodontic materials in terms of plaque accumulation*

Incorporating digital technology to enhance patient care is a professional responsibility that relies on ongoing research and innovation, supported by reliable data collection [41]. Traditional methods for estimating plaque, such as dye application followed by visual assessment, are prone to error, operator bias, and can be time-consuming and costly [43]. Light-induced fluorescence devices mitigate many of these limitations, enabling the detection of subtle changes in tooth mineral content and providing a convenient and accurate tool for research purposes [43].

#### *Fluorescence-enhanced theragnosis—the next step in targeted diagnostics*

Daylight and magnification have long been essential for oral diagnosis and treatment planning. Fluorescence allows the creation of photoluminescence with specific light spectra, visualized through specialized filters, exploiting the natural fluorescence of tooth structures and porphyrins produced by caries-causing bacteria. This approach enables direct visual treatment, offering patients controlled and guided therapy. Fluorescence-enhanced theragnosis provides multiple benefits, including early caries detection, biofilm identification, and improved treatment outcomes through informed resin selection for esthetic procedures (**Figure 4**). For demineralization diagnosis, its effectiveness is enhanced when combined with external fluorophores targeting calcium ions, though further clinical trials are required to validate its routine use in dentistry. Continued research is needed to fully integrate fluorescence-enhanced theragnosis as a reliable diagnostic and treatment-planning tool in orthodontics, given its substantial potential.



**Figure 4.** Fluorescent light provides a precise method to detect demineralized zones, carious lesions, and plaque accumulation around teeth

#### *Opportunities for advancement*

The application of fluorescence-enhanced theragnosis can be facilitated using wearable tools such as the Reveal device (Designs for Vision, Inc., Bohemia, NY, USA) [44]. This system integrates magnifying loupes into protective eyewear, incorporating multiple coatings to shield the eyes from the emitted light. As usage becomes

more widespread and production scales up, the cost could decrease, allowing broader adoption among orthodontic practitioners.

## Conclusion

With the rise of digital technologies, orthodontics has consistently embraced innovations to improve patient care. Continuous monitoring of treatment progress plays a crucial role in achieving optimal outcomes. In the words of Aristotle, “Well begun is half done,” highlighting the importance of initiating treatment with tools and strategies that ensure precise tracking and guidance throughout therapy.

**Acknowledgments:** None

**Conflict of interest:** None

**Financial support:** None

**Ethics statement:** None

## References

1. Paster BJ, Boches SK, Galvin JL, Ericson RE, Lau CN, Levanos VA, Sahasrabudhe A, Dewhirst FE. Bacterial diversity in human subgingival plaque. *J Bacteriol.* 2001;183(12):3770–83.
2. Kolenbrander PE. Oral microbial communities: biofilms, interactions, and genetic systems. *Annu Rev Microbiol.* 2000;54:413–37.
3. Kornman KS, Page RC, Tonetti MS. The host response to the microbial challenge in periodontitis: assembling the players. *Periodontol 2000.* 1997;14:33–53.
4. Haffajee AD, Socransky SS. Microbial etiological agents of destructive periodontal diseases. *Periodontol 2000.* 1994;5:78–111.
5. Armitage GC, Robertson PB. The biology, prevention, diagnosis and treatment of periodontal diseases: scientific advances in the United States. *J Am Dent Assoc.* 2009;140(Suppl 1):36S–43S.
6. Offenbacher S. Periodontal diseases: pathogenesis. *Ann Periodontol.* 1996;1(1):821–78.
7. Sharma NC, Qaish J, Klukowska M, Grender J, Rooney J. The plaque removal efficacy of a novel power brush head. *J Clin Dent.* 2011;22(1):19–22.
8. Raggio DP, Braga MM, Rodrigues JA, Freitas PM, Imparato JCP, Mendes F. Reliability and discriminatory power of methods for dental plaque quantification. *J Appl Oral Sci.* 2010;18(2):186–93.
9. Yavan MA, Kocahan S, Ozdemir S, Sokucu O. The effects of using plaque-disclosing tablets on the removal of plaque and gingival status of orthodontic patients. *Turk J Orthod.* 2019;32(4):207–14.
10. Øgaard B, Ten Bosch JJ. Regression of white spot enamel lesions: a new optical method for quantitative longitudinal evaluation in vivo. *Am J Orthod Dentofacial Orthop.* 1994;106:238–42.
11. Silness J, Løe H. Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand.* 1964;22:121–35.
12. Pretty IA, Pender N, Edgar WM, Higham SM. The in vitro detection of early enamel de- and remineralization adjacent to bonded orthodontic cleats using quantitative light-induced fluorescence. *Eur J Orthod.* 2003;25(3):217–23.
13. Gray D, McIntyre G. Does oral health promotion influence the oral hygiene and gingival health of patients undergoing fixed appliance orthodontic treatment? A systematic literature review. *J Orthod.* 2008;35(4):262–9.
14. Marini I, Bortolotti F, Parenti SI, Gatto MR, Bonetti GA. Combined effects of repeated oral hygiene motivation and type of toothbrush on orthodontic patients: a blind randomized clinical trial. *Angle Orthod.* 2014;84(5):896–901.
15. Boyd RL. Longitudinal evaluation of a system for self-monitoring plaque control effectiveness in orthodontic patients. *J Clin Periodontol.* 1983;10:380–8.
16. Richter DD, Nanda RS, Sinha PK, Smith DW, Currier GF. Effect of behavior modification on patient compliance in orthodontics. *Angle Orthod.* 1998;68(2):123–32.

17. Lalic M, Aleksic E, Gajic M, Milic J, Malesevic D. Does oral health counseling effectively improve oral hygiene of orthodontic patients? *Eur J Paediatr Dent.* 2012;13(3):181–6.
18. Eppright M, Shroff B, Best A, Barcoma E, Lindauer SJ. Influence of active reminders on oral hygiene compliance in orthodontic patients. *Angle Orthod.* 2014;84(2):208–13. (Epub 2013 Sep 12)
19. Marsh PD. Dental plaque as a biofilm and a microbial community: implications for health and disease. *BMC Oral Health.* 2006;6(Suppl 1):S14. (Supplement; article S14)
20. Anil K, Anand A. *Fundamentals and Applications of Biophotonics in Dentistry.* London: Imperial College Press; 2007. p. 16–7.
21. Walsh LJ, Shakibaie F. Ultraviolet-induced fluorescence: shedding new light on dental biofilms and dental caries. *Australas Dent Pract.* 2007;18(4):1–7.
22. Heinrich-Weltzien R, Kühnisch J, van der Veen M, de Jong E, Stösser L. Quantitative light-induced fluorescence (QLF)—a potential method for the dental practitioner. *Quintessence Int.* 2003;34(3):181–8.
23. Volgenant CM, Hoogenkamp MA, Buijs MJ, Zaura E, ten Cate JM, van der Veen MH. Red fluorescent biofilm: the thick, the old, and the cariogenic. *J Oral Microbiol.* 2016;8:30346. (article ID)
24. Biamonte F, Buffone C, Santamaria G, Battaglia AM, Mignogna C, Fortunato L, Costanzo FS, Giudice A. Gene expression analysis of autofluorescence margins in leukoplakia and oral carcinoma: a pilot study. *Oral Dis.* 2021;27(1):193–203.
25. Giudice A, Bennardo F, Barone S, Antonelli A, Figliuzzi M, Fortunato L. Can autofluorescence guide surgeons in the treatment of medication-related osteonecrosis of the jaw? A prospective feasibility study. *J Oral Maxillofac Surg.* 2018;76(5):982–95.
26. Karkhanechi M, Chow D, Sipkin J, Sherman D, Boylan RJ, Norman RG, Craig RG, Cisneros GJ. Periodontal status of adult patients treated with fixed buccal appliances and removable aligners over one year of active orthodontic therapy. *Angle Orthod.* 2013;83(1):146–51.
27. Alexander SA. Effects of orthodontic attachments on the gingival health of permanent second molars. *Am J Orthod Dentofacial Orthop.* 1991;100(4):337–40.
28. Ristic M, Svabic MV, Sasic M, Zelic O. Clinical and microbiological effects of fixed orthodontic appliances on periodontal tissues in adolescents. *Orthod Craniofac Res.* 2007;10(3):187–95.
29. Butera A, Gallo S, Maiorani C, Molino D, Chiesa A, Preda C, Esposito F, Scribante A. Probiotic alternative to chlorhexidine in periodontal therapy: evaluation of clinical and microbiological parameters. *Microorganisms.* 2021;9(1):69.
30. Preda C, Butera A, Pelle S, Pautasso E, Chiesa A, Esposito F, Oldoini G, Scribante A, Genovesi A, Cosola S. The efficacy of powered oscillating heads vs. powered sonic action heads toothbrushes to maintain periodontal and peri-implant health: a narrative review. *Int J Environ Res Public Health.* 2021;18(4):1468.
31. Bollen AM, Cunha-Cruz J, Bakko DW, Huang GJ, Hujoel PP. The effects of orthodontic therapy on periodontal health: a systematic review of controlled evidence. *J Am Dent Assoc.* 2008;139(5):413–22.
32. Miller CC, Burnside G, Higham SM, Flannigan NL. Quantitative light-induced fluorescence-digital as an oral hygiene evaluation tool to assess plaque accumulation and enamel demineralization in orthodontics. *Angle Orthod.* 2016;86(6):991–7.
33. Şen S, Erber R, Deurer N, Orhan G, Lux CJ, Zingler S. Demineralization detection in orthodontics using an ophthalmic optical coherence tomography device equipped with a multicolor fluorescence module. *Clin Oral Investig.* 2020;24(8):2579–90.
34. Scribante A, Farahani MRD, Marino G, Matera C, Baena RRY, Lanteri V, Butera A. Biomimetic effect of nano-hydroxyapatite in demineralized enamel before orthodontic bonding of brackets and attachments: visual, adhesion strength, and hardness in *in vitro* tests. *Biomed Res Int.* 2020;2020:Article ID 1–9.
35. O'Reilly MM, Featherstone JD. Demineralization and remineralization around orthodontic appliances: an *in vivo* study. *Am J Orthod Dentofacial Orthop.* 1987;92(1):33–40.
36. van der Veen MH, de Josselin de Jong E. Application of quantitative light-induced fluorescence for assessing early caries lesions. *Monogr Oral Sci.* 2000;17:144–62.
37. Al-Khateeb S, Forsberg CM, de Josselin de Jong E, Angmar-Månsson B. A longitudinal laser fluorescence study of white spot lesions in orthodontic patients. *Am J Orthod Dentofacial Orthop.* 1998;113(6):595–602.
38. Ren Y, Jongsma MA, Mei L, van der Mei HC, Busscher HJ. Orthodontic treatment with fixed appliances and biofilm formation—a potential public health threat? *Clin Oral Investig.* 2014;18(6):1711–8.

39. Fontana M, Young DA, Wolff MS. Evidence-based caries risk assessment and treatment. *Dent Clin North Am.* 2009;53(1):149–61.
40. Lussi A, Hibst R, Paulus R. DIAGNOdent: an optical method for caries detection. *J Dent Res.* 2004;83(Spec Issue):80–3
41. Pignatta LMB, Júnior SD, Santos ECA. Evaluation of enamel surface after bracket debonding and polishing. *Dent Press J Orthod.* 2012;17(2):77–84.
42. Murray PG, Millett DT, Cronin M. Bonded molar tubes: a survey of their use by specialist orthodontists. *J Orthod.* 2012;39(2):129–35.
43. Kim HE. Quantitative light-induced fluorescence: a potential tool for dental hygiene process. *J Dent Hyg Sci.* 2013;13(2):115–24.
44. Steier L. Reveal: fluorescence enhanced theragnosis by Designs for Vision. *Eur J Dent.* 2020;14(1):186–8.