Methods FOR Evaluating THE Effectiveness OF Home Oral Hygiene Measures: A Narrative Review OF Dental Biofilm Indices

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Abstract:

Dental plaque, a biofilm composed of microorganisms embedded in an extracellular matrix, plays a key role in the development of both periodontal diseases and dental caries. Under certain conditions, the relationship between the host and the oral microbiome can shift from symbiotic to dysbiotic, leading to pathological changes in the hard and soft tissues. Assessing the effectiveness of home oral hygiene measures is critical for preventing these common oral diseases and promoting optimal oral health. Dental plaque indices provide a means of quantifying and monitoring plaque levels, but the sheer number and variety of these indices can make it challenging for clinicians and researchers to select the most appropriate one for a given purpose. This narrative review aims to provide a comprehensive overview of the various methods available for evaluating dental biofilm, with a focus on categorizing indices as either non-quantitative or quantitative. Non-quantitative indices rely on subjective assessments of plaque presence and extent, while quantitative indices employ objective measures such as plaque weight, planimetric

analysis, or light-induced fluorescence. Understanding the strengths and limitations of these different plaque scoring methods is essential for their effective application in clinical practice, epidemiological surveys, and research settings. By critically examining the full spectrum of dental biofilm indices, this review serves as a valuable resource for oral health professionals seeking to optimize oral hygiene assessment and tailor preventive strategies to the individual needs of their patients.

Introduction:

Dental plaque is a complex biofilm that forms on tooth surfaces and other oral structures, composed of diverse microbial communities enmeshed in an extracellular matrix of polymers derived from both host and bacterial sources [1]. Under healthy conditions, the oral microbiome exists in a state of symbiosis with the host. However, environmental perturbations can disrupt this delicate balance, leading to dysbiosis and the development of oral diseases such as periodontal disease and dental caries [2-4].

Periodontal disease pathogenesis involves a progression from reversible gingival inflammation (gingivitis) to irreversible destruction of the supporting tissues (periodontitis) in susceptible individuals. While the presence of specific microorganisms in dental plaque is necessary for periodontitis to occur, it is not sufficient in itself; rather, it is the interaction between the dysbiotic biofilm and the host immune response that ultimately leads to clinical attachment loss and alveolar bone resorption [5,6]. Similarly, dental caries results from the metabolic activity of acidogenic bacteria in dental plaque, which leads to demineralization of the tooth structure when the balance between demineralization and remineralization is disrupted [7].

Given the etiological role of dental plaque in these common oral diseases, biofilm control is a cornerstone of prevention and treatment. Mechanical removal of plaque through regular toothbrushing and interdental cleaning is widely recognized as the most effective means of maintaining oral health [8]. Antimicrobial agents in dentifrices and mouthrinses can also aid in chemical plaque control [9]. Evaluating the efficacy of

these various home oral hygiene measures requires the use of reliable and valid plaque indices.

Dental plaque indices provide a means of quantifying and monitoring plaque levels, allowing clinicians and researchers to assess the oral hygiene status of individual patients, compare the effectiveness of different oral hygiene regimens, and study the relationship between plaque and oral diseases [10]. However, the plethora of available indices, each with its own unique features and methodological considerations, can make it difficult to determine which one is most suitable for a particular purpose.

This narrative review aims to provide a comprehensive overview of the various methods for evaluating dental biofilm, with an emphasis on categorizing plaque indices as either non-quantitative or quantitative. Non-quantitative indices rely on subjective assessments of plaque presence and extent using criteria such as area coverage, thickness, or gingival proximity. In contrast, quantitative indices employ objective measures such as plaque weight, planimetric analysis of dental images, or light-induced fluorescence. By critically examining the strengths and limitations of these different approaches to plaque scoring, this review serves as a resource for clinicians and researchers seeking to optimize oral hygiene assessment in clinical practice, epidemiological surveys, and research settings.

The ultimate goal of understanding and effectively applying dental plaque indices is to tailor preventive and therapeutic strategies to the individual needs of each patient. Personalizing oral hygiene recommendations based on an individual's unique plaque profile and risk factors can improve patient motivation, compliance, and outcomes. Furthermore, the use of appropriate plaque indices in research can help to advance our understanding of the complex interactions between the oral microbiome, host response, and environmental factors that drive disease processes. As new technologies emerge for imaging and analyzing dental biofilm, it is important to continually reassess and refine our methods for evaluating the effectiveness of home oral hygiene measures. This review contributes to that ongoing process by providing a narrative

synthesis of the current state of knowledge on dental plaque indices.

Assessment of Oral and Dental Biofilm:

Classification and Features of Plaque Indices: Dental plaque indices can be classified based on several key features that reflect their design, scope, and intended applications. One important distinction is between non-quantitative and quantitative indices. Non-quantitative indices rely on subjective assessments of plaque presence and extent by a clinician or researcher. These indices typically use ordinal scales with defined criteria for each score, but do not provide a true numerical measure of plaque quantity. In contrast, quantitative indices aim to measure plaque deposits objectively using methods such as weight, planimetric analysis of dental images, or light-induced fluorescence [11].

Another way to categorize plaque indices is as either full mouth or partial mouth assessments. Full mouth indices score plaque on all available tooth surfaces, while partial mouth indices examine only a selected subset of teeth or sites. Partial mouth indices, such as those utilizing the Ramfjord teeth (6 representative teeth: upper right 1st molar, central incisor, 1st premolar; lower left 1st molar, central incisor, 1st premolar), can reduce examination time while still providing a reasonable estimate of whole mouth plaque levels [12].

Plaque indices may also be distinguished by their focus on specific aspects of the biofilm, such as its extent, thickness, or location in relation to the gingival margin. Some indices prioritize plaque coverage, using defined criteria to estimate the percentage of tooth surface area covered by plaque. Others place greater emphasis on plaque thickness, recognizing that thicker deposits along the gingival margin may be more significant in the development of periodontal inflammation. The design of a plaque index generally reflects its intended purpose, such as epidemiological surveys, clinical trials, or monitoring patient oral hygiene and motivation over time [13].

Regardless of their specific features, all plaque indices should ideally be simple, efficient, reliable, and discriminating. The scoring criteria should be clearly defined and the number of categories limited to minimize subjectivity and examiner

variability. The index should be quick and easy to apply, requiring minimal specialized equipment beyond the basic dental armamentarium. Examiners should be calibrated to ensure acceptable intra- and inter-examiner reliability. Finally, the index should be sensitive enough to detect meaningful differences in plaque levels between individuals, groups, or time points [10,13].

Disclosing Agents:

Dental plaque is normally invisible to the naked eye due to its pale color that blends with the tooth surface. Disclosing agents contain dyes or other coloring agents that stain plaque deposits, enhancing their contrast against the enamel background. The two main mechanisms of plaque disclosure are based on either the polarity differences between the dye molecules and plaque components or the metabolic activity of plaque bacteria [14].

Common disclosing agents include iodine, erythrosine, basic fuchsin, and two-tone dyes that differentially stain younger and older plaque deposits. Disclosing agents serve three main functions: 1) to reveal plaque deposits for assessment with a visual index; 2) to guide plaque removal during oral hygiene instruction; and 3) to provide feedback and motivation for patients to improve their oral self-care [15].

While disclosing agents are widely used and generally considered beneficial, they do have some drawbacks. The staining process adds an extra step and may be time-consuming, especially if a full mouth index is being performed. Some patients, particularly children or those with cognitive impairments, may object to the taste or sensation of the disclosing solution. The temporary staining of the lips, tongue, and mucosa can also be aesthetically displeasing. Certain dyes, like erythrosine, have been reported to enhance plaque regrowth in the 24 hours following their use [16]. Thus, the use of disclosing agents should be judiciously considered based on the specific clinical or research scenario.

Non-Quantitative Methods:

Non-quantitative plaque indices rely on direct visual inspection of the dentition, with or without the aid of disclosing agents, to assess the presence and extent of plaque deposits. Scoring is

based on defined criteria, typically using an ordinal scale ranging from zero (no plaque) to a maximum value representing severe plaque accumulation. While non-quantitative indices are inherently subjective, their simplicity and efficiency make them popular for clinical and epidemiological applications.

Some of the most widely used non-quantitative plaque indices include the Plaque Index (PI) [17], the Simplified Oral Hygiene Index (OHI-S) [18], the Modified Quigley-Hein Plaque Index [19], and the Navy Plaque Index [20]. These indices differ in the specific teeth and surfaces scored, the scaling criteria, and the use of disclosing agents. For example, the PI scores plaque thickness on six representative teeth using a 0-3 scale, while the OHI-S assesses plaque extent on selected buccal and lingual surfaces using a 0-3 scale plus a separate calculus component. The Modified Quigley-Hein Index examines facial and lingual plaque coverage on all teeth after disclosing, using a 0-5 scale.

Several non-quantitative indices focus specifically on plaque deposits adjacent to the gingival margin, reflecting the importance of this region in periodontal pathology. These include the Gingival Margin Plaque Index [21], which scores the presence or absence of disclosed plaque at the gingival margin, and the Plaque-Free Score Index [22], which calculates the percentage of gingival margins without plaque.

Despite their subjectivity, non-quantitative plaque indices remain useful tools for assessing oral hygiene status and evaluating the effectiveness of plaque control measures. Advantages include their simplicity, versatility, and low cost. However, these indices are limited in their ability to quantify plaque levels and detect small changes over time. They are also dependent on examiner skill and calibration to achieve acceptable reliability. Combining findings from multiple non-quantitative indices and supplementing them with objective measures can help to offset these limitations.

Quantitative Methods:

Quantitative plaque indices aim to measure plaque deposits objectively using physical or optical properties such as mass, area coverage, thickness, or fluorescence. While more technologically complex and less widely used than non-

quantitative indices, quantitative methods offer the potential for greater precision and sensitivity in clinical trials and other research applications.

Gravimetric methods were among the earliest quantitative approaches, using microbalances to determine plaque wet or dry weight [23]. However, these methods proved cumbersome and unreliable due to issues with plaque collection, desiccation, and contamination. Planimetric methods emerged as an alternative, using dental photographs or video images to calculate the percentage of tooth surface area covered by disclosed plaque [24]. Planimetric analysis originally required manual tracing of plaque outlines on printed images, but has since been automated using digital image analysis software [25].

Another approach to quantitative plaque assessment is based on dental optical properties, specifically the red fluorescence of porphyrins produced by certain oral bacteria when illuminated with blue light. Quantitative light-induced fluorescence (QLF) systems capture digital images of disclosed plaque deposits and analyze their area and intensity to generate a numerical plaque score [26]. QLF has been shown to correlate well with clinical indices and offers the advantage of an automated, user-friendly platform for rapid plaque quantification [27].

Recent advances in imaging technology and machine learning have paved the way for even more sophisticated methods of quantitative plaque assessment. Multispectral imaging, which captures image data at multiple wavelengths, can be used to discriminate between plaque and other oral structures based on their unique spectral signatures [28]. Convolutional neural networks and other deep learning algorithms have been applied to automatically detect and quantify plaque deposits from white light and fluorescence images with high accuracy [29].

While quantitative plaque indices offer objective data and potential advantages in terms of precision and reproducibility, they also have significant drawbacks. The instrumentation required is often expensive, complex, and requires specialized training to operate. The time needed for image acquisition, processing, and analysis may be impractical for routine clinical

use. Methodological standardization is lacking, making it difficult to compare results across studies. Finally, the clinical significance of small numerical differences in plaque scores is not always clear. Therefore, quantitative plaque assessment is currently most suitable for research settings, while non-quantitative indices remain the standard of care for clinical practice.

Ultimately, the choice of plaque index should be dictated by the specific goals and constraints of the clinical or research setting. A simple, non-quantitative index may be most appropriate for screening large populations or monitoring individual patient progress over time. More sophisticated quantitative methods may be indicated for evaluating the efficacy of new oral hygiene products or investigating the fine details of plaque composition and metabolism. Understanding the strengths and limitations of each approach is key to selecting the most valid and reliable tool for the task at hand.

Conclusion:

Dental plaque indices are essential tools for assessing oral hygiene status, monitoring disease risk, and evaluating the effectiveness of preventive and therapeutic interventions. This narrative review has provided an overview of the various non-quantitative and quantitative methods available for measuring dental biofilm, highlighting their key features, advantages, and limitations.

Non-quantitative indices, such as the Plaque Index, Simplified Oral Hygiene Index, and Modified Quigley-Hein Index, rely on visual inspection and defined scoring criteria to assess plaque presence and extent. These indices are widely used in clinical practice and epidemiological surveys due to their simplicity, versatility, and low cost. However, they are inherently subjective and may lack the precision and sensitivity to detect small changes in plaque levels over time.

Quantitative indices aim to overcome these limitations by using objective measures such as plaque weight, area coverage, or fluorescence intensity. Planimetric methods, which analyze digital images of disclosed plaque, have become increasingly automated and standardized. Quantitative light-induced fluorescence (QLF) systems offer a rapid, user-friendly platform for plaque quantification based on the red fluorescence of

bacterial porphyrins. Emerging technologies such as multispectral imaging and deep learning algorithms show promise for even more precise and automated plaque assessment in the future.

Despite the potential advantages of quantitative methods, they also have significant drawbacks in terms of cost, complexity, and time requirements. Non-quantitative indices remain the standard of care for routine clinical use, while quantitative methods are currently most suitable for research settings. The choice of plaque index should be carefully considered based on the specific goals, resources, and limitations of the clinical or research context.

Ultimately, the value of any plaque index lies in its ability to inform patient care and advance our understanding of oral health and disease. Dental biofilm assessment should not be viewed as an end in itself, but rather as a means to tailor preventive and therapeutic strategies to the individual needs of each patient. Plaque indices can serve as powerful motivational tools, providing patients with tangible feedback on their oral hygiene efforts and empowering them to take an active role in their own oral health.

As new technologies and analytical methods continue to emerge, it is important for clinicians and researchers to stay informed about the evolving landscape of dental biofilm assessment. Future research should focus on validating novel plaque measurement approaches, standardizing protocols for data acquisition and analysis, and clarifying the clinical significance of quantitative plaque parameters. At the same time, efforts should be made to optimize existing non-quantitative indices and explore ways to integrate them with objective measures for a more comprehensive assessment of oral hygiene status.

Effective plaque control remains the cornerstone of preventive dentistry and periodontal therapy. By understanding the strengths and limitations of different plaque indices and selecting the most appropriate tool for each situation, oral health professionals can better assess risk, monitor progress, and make evidence-based decisions to promote optimal oral health for their patients. This narrative review serves as a resource to guide clinicians and researchers in this important

endeavor, contributing to the ongoing advancement of preventive and personalized oral healthcare.

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