10-1-2021

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Karo Parsegian

Srinivas Ayilavarapu

Tulsi Patel

Harold A Henson

Nikola Angelov

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Karo Parsegian*, DMD, MDSc, PhD; **Srinivas Ayilavarapu***, DSc, MDS; **Tulsi Patel***, BSDH, MHA, RDH; **Harold A Henson***, PhD, RDH; **Nikola Angelov***, DDS, PhD

PRACTICAL IMPLICATIONS OF THIS RESEARCH

- Understanding diagnostic determinants is essential to accurately diagnosing periodontal conditions.
- Dental and dental hygiene students with limited exposure to didactic periodontics and clinical care of clients with periodontal conditions may have inadequate skills to accurately diagnose them without the use of additional educational aids.
- Flowcharts offer a straightforward approach to improving the accuracy of diagnosing periodontal conditions in a time-effective manner.

ABSTRACT

Background: In 2017, the American Academy of Periodontology and the European Federation of Periodontology updated the classification of periodontal and peri-implant diseases and conditions. The goal of the present crossover study was to develop straightforward, illustrative flowcharts and determine their impact on the accuracy and speed of diagnosing periodontal conditions by predoctoral dental students (DS) and dental hygiene students (DHS). **Methods:** Two flowcharts (a decision-tree flowchart and one based on the periodontal disease/condition entity) were developed using updated diagnostic determinants proposed by the 2017 classification. A total of 26 second-, third-, and fourth-year DS (DS2, DS3, and DS4, respectively) and second-year DHS (DHS2) took a mock examination consisting of 10 periodontal clinical cases. The participants first diagnosed periodontal conditions using only their curricula-based knowledge (control) and then using the flowcharts (test). They also completed an optional post-examination questionnaire to provide feedback on the flowcharts. Statistical significance was detected at $p \leq 0.05$. **Results:** Combined test groups had significantly higher accuracy in diagnosing periodontal conditions compared to controls (73.5% vs 50.0%, respectively), with the most substantial improvement in DS2 (66.3% vs 30%, respectively) and DHS2 (70.0% vs 41.4%, respectively). Combined test groups also completed the examination more quickly compared to controls (14.92 vs 20.85 minutes, respectively). The participants provided positive feedback and constructive criticism on the flowcharts, and also suggested converting them into application software. **Conclusion:** The flowcharts significantly improved the accuracy of diagnosing periodontal conditions in academic settings, especially among junior, less experienced participants.

RÉSUMÉ

Contexte : En 2017, l'Académie américaine de parodontologie et la Fédération européenne de parodontologie ont mis à jour leur classification des maladies et des affections parodontales et péri-implantaires. L'objectif de la présente étude croisée était de créer des organigrammes simples et représentatifs et de déterminer leur effet sur l'exactitude et la vitesse de diagnostic des affections parodontales par les étudiants en médecine dentaire, prédoctorat (ÉD) et les étudiants en hygiène dentaire (ÉHD). **Méthodes :** Deux organigrammes (un organigramme d'arbre décisionnel et un graphique basé sur l'entité de la maladie ou de l'affection parodontale) ont été élaborés à l'aide des déterminants diagnostiques actualisés, comme proposés dans la classification de 2017. Un total de 26 étudiants de deuxième, troisième et quatrième année (ÉD2, ÉD3 et ÉD4, respectivement) en médecine dentaire et des étudiants de deuxième année en hygiène dentaire (ÉHD2) ont passé un examen fictif portant sur 10 cas cliniques parodontaux. Les participants ont d'abord diagnostiqué les affections parodontales en utilisant seulement leurs connaissances fondées sur leur programme d'études (témoins) et en utilisant ensuite les organigrammes (tests). Ils ont aussi rempli un questionnaire optionnel après avoir passé l'examen afin de fournir des commentaires sur les organigrammes. La signification statistique a été décelée à $p \leq 0{,}05$. **Résultats :** Les groupes de tests combinés avaient une exactitude considérablement plus élevée dans le diagnostic des affections parodontales par rapport aux groupes témoins (73,5 % contre 50,0 %, respectivement), et l'amélioration la plus importante était chez les ÉD2 (66,3 % contre 30 %, respectivement) et les ÉHD2 (70,0 % contre 41,4 %, respectivement). Les groupes de tests combinés ont aussi terminé l'examen plus rapidement par rapport aux groupes témoins (14,92 contre 20,85 minutes, respectivement). Les participants ont fourni des commentaires positifs et des critiques constructives sur les organigrammes et ont aussi suggéré de les convertir en logiciels d'application. **Conclusion :** Les organigrammes ont considérablement amélioré l'exactitude du diagnostic des affections parodontales dans les milieux d'enseignement, surtout chez les participants débutants et moins expérimentés.

Keywords: decision trees; dental hygiene; education, dental; periodontal diseases; periodontics; students, dental; surveys and questionnaires
CDHA Research Agenda category: capacity building of the profession

*Department of Periodontics and Dental Hygiene, University of Texas Health Science Center at Houston, School of Dentistry, Houston, TX, USA

Correspondence: Dr. Karo Parsegian; karo.parsegian@uth.tmc.edu
Manuscript submitted 4 February 2021; revised 25 May 2021; accepted 31 May 2021

INTRODUCTION

Periodontal diseases, including gingivitis and periodontitis, are multifactorial conditions of inflammatory origin that involve complex interactions between the microbiota, a susceptible host, and contributory environmental and epigenetic factors.[1,2] Both gingivitis and periodontitis are among the most common inflammatory diseases diagnosed in 32% to 53%[3,4] and 42%[5] of US adults, respectively. Therefore, understanding their clinical signs and symptoms is essential for periodontists, dental hygienists, general practitioners, and other oral health professionals to diagnose and successfully manage clients with periodontal conditions.

At the 2017 World Workshop in Periodontics, both the American Academy of Periodontology (AAP) and the European Federation of Periodontology (EFP) presented the updated Classification of Periodontal and Peri-Implant Diseases and Conditions,[6] which replaced the classification system used since 1999.[7] The new classification aimed to address several deficiencies and confusing points in the 1999 classification, which were comprehensively discussed in a series of publications and summarized in Table 1. The key changes were reflected in the precise definitions of clinical gingival (periodontal) health[6,8] and biofilm-induced gingivitis (both conditions could be diagnosed on an intact and reduced periodontium),[6,8-10] and the new concept of periodontitis[11,12] based on the staging and grading system (adapted, to a certain extent, from the staging diagnosis description system in oncology). In contrast to the 1999 classification, which determined the severity of periodontitis based on the previous periodontal breakdown, the new classification uses various diagnostic determinants to establish the disease severity and complexity (a staging concept), progression and risk factors (a grading concept), and extent (localized and generalized).[6,11] The diagnosis of periodontal conditions is established based on the presence and extent of clinical attachment levels (CAL), radiographic bone loss (RBL), pocket depth (PD), and bleeding on probing (BOP).

Several studies demonstrated that the proposed classification updates accurately reflected client characteristics and improved the diagnostic accuracy of periodontal conditions.[13] A recent National Health and Nutrition Examination Survey III-based study also showed

Table 1. Changes proposed to the classification of periodontal diseases and conditions by the 2017 World Workshop of Periodontics

Periodontal condition	Changes
Periodontal (gingival) health[6,16]	• Introduced a section on periodontal (gingival) health
Dental biofilm-induced gingivitis[9]	• Accepted bleeding on probing (BOP) as the single reliable criterion to evaluate gingival inflammation • Defined a "gingivitis case" • Introduced the term "dental biofilm" • Provided clear-cut criteria to discriminate a client with gingivitis vs gingival health • Provided criteria to discriminate between localized vs generalized gingivitis
Non-dental biofilm-induced gingival diseases[22]	• Introduced comprehensive nomenclature for pathological gingival conditions • Used the Tenth International Classification of Diseases (ICD-10) diagnostic codes to classify and code all diagnoses, symptoms, and procedures recorded in conjunction with hospital care in the USA
Periodontitis[11,12,19,23]	• Defined a periodontitis case • Introduced the staging and grading concepts of periodontitis • Eliminated aggressive periodontitis as a separate disease entity due to insufficient evidence to consider its pathophysiology different from chronic periodontitis
Necrotizing periodontal diseases[22]	• Introduced the term "necrotizing periodontal diseases" • Eliminated the term "ulcerative" from necrotizing gingivitis, periodontitis, and stomatitis
Periodontitis as a manifestation of systemic diseases[24]	• Used the Tenth International Classification of Diseases (ICD-10) diagnostic codes to classify and code all diagnoses, symptoms, and procedures recorded in conjunction with hospital care in the USA
Systemic diseases or conditions affecting periodontal supporting tissues[25]	• Used ICD-10 codes to classify the primary systemic disease
Periodontal abscesses[26]	• Eliminated the term "acute" from the diagnosis of abscesses • Eliminated the terms "pericoronal abscess" and "pericoronitis abscess"
Endodontic-periodontal lesions (EPLs)[26]	• Grouped all EPLs under a single section "Periodontitis Associated with Endodontic Lesion" since they can occur in clients with or without periodontitis • Eliminated the category "Combined EPLs" since it was too generic and did not allow for specific, discriminatory treatments for each lesion
Mucogingival deformities and conditions[27]	• Introduced the classification of gingival recession by Cairo as a part of the periodontal classification • Included types of periodontal biotypes
Traumatic occlusal forces[28]	• Included orthodontic forces
Dental prostheses- and tooth-related factors[29]	• Replaced the term "biological width" with "supracrestal connective tissue attachment"
Peri-implant diseases and conditions[30]	• Introduced peri-implant diseases and conditions

that the updated periodontitis case definitions improved the accuracy performance of full-mouth partial diagnostic protocols compared to those proposed by AAP and the Centers for Disease Control in 2012.[14]

Although the criteria defining these conditions were clearly described, their chairside application might pose some challenges due, at least in part, to a similar array of determinants used to diagnose different periodontal conditions, shared etiologies of these diseases (such as periodontitis and gingival recession of an inflammatory origin), and unclear thresholds for certain periodontal conditions (such as reduced periodontium). A variety of possible clinical scenarios with overlapping clinical and radiographic findings resulted in "gray zones," which made the accuracy of a periodontal diagnosis even more challenging.[12] To promote the comprehension of the diagnosis of periodontitis (including stages and grades), AAP and EFP published several illustrative diagrams and tables.[6,11] However, they did not include decision-tree approaches to establishing a diagnosis of periodontitis and other gingival/periodontal conditions (such as clinical gingival health, gingivitis, and CAL associated with the gingival recession). Such approaches might be especially helpful for individuals who have limited experience in periodontics and may find a differential diagnosis of these conditions confusing. For example, non-periodontists found the new classification challenging to comprehend and apply chairside, as evidenced by significantly lower accuracy of periodontal diagnosis compared to periodontal residents.[15] Although this difference could be due to the staging and grading system of the new classification not yet being commonly incorporated into curricula outside of graduate periodontics, it could also indicate that individuals with limited exposure to periodontics and periodontal classification find the currently available illustrative approaches inadequate for their needs.

Similar to non-periodontists, predoctoral dental students (DS) and dental hygiene students (DHS) commonly have limited exposure to periodontics, and therefore, may be less accurate in diagnosing periodontal diseases. In addition, since the classification was introduced to dental curricula relatively recently, these students have not had long-term, repeated exposure to it. However, their ability to accurately diagnose periodontal conditions is essential for an appropriate and clinically justified treatment choice. Therefore, the goals of the present crossover study were to 1) develop straightforward and illustrative flowcharts of periodontal conditions and 2) evaluate their impact on the accuracy and speed of diagnosing periodontal conditions by DS and DHS. The outcomes of the study will be helpful for DS and DHS to better understand the 2017 periodontal classification and apply it chairside.

METHODS

Development of the flowcharts

The flowcharts were developed by the first author (KP) based on the reviewed articles outlining the 2017 World Workshop in Periodontics (and referenced in the study). Two flowcharts were constructed. The first one represented a decision tree that uses a series of straightforward questions to lead users to make a diagnosis of clinical gingival health (on an intact and reduced periodontium),[6,8,16] gingivitis (on an intact and reduced periodontium),[6,9,17] periodontitis,[6,11] and outcomes of periodontal treatment[16] (Figure 1). Since CAL is considered a key diagnostic determinant of the 2017 classification,[11,12] the first question that users are asked is whether a client presents with CAL and, if so, is it associated with periodontal (inflammatory) or non-periodontal (non-inflammatory) factors. If the client has no CAL, then the diagnosis depends on the percentage of BOP+ sites (clinical gingival health on an intact periodontium for BOP <10%[8,16] and dental biofilm-induced gingivitis [localized or generalized] on an intact periodontium for BOP ≥10%).[8,9,17] If the client has CAL associated with non-periodontal factors (listed in Figure 1), they are diagnosed with either clinical gingival health or biofilm-induced gingivitis (both on a reduced periodontium) based on the same BOP criteria as for the respective conditions on an intact periodontium. If a client has CAL due to periodontal breakdown, the next question is whether that client has a history of periodontal treatment and regular periodontal maintenance. If the client has no history of periodontal treatment and regular periodontal maintenance or is treated and maintained adequately but still displays progressive (≥2 mm) CAL, then they would be diagnosed with active periodontitis,[8,18] and its extent, stage, and grade should be determined according to the established criteria.[8,11,19] If a client has a history of periodontal treatment followed by regular periodontal maintenance, then they could be diagnosed with clinical gingival health on a reduced periodontium in a stable periodontitis client,[8,16] gingivitis on a reduced periodontium in a stable periodontitis client,[8] and periodontal disease in remission/control on a reduced periodontium.[16] The differences between these diagnoses depend on BOP and PD.[8]

The second flowchart provides an alternative, disease-entity-based approach to diagnosing periodontal conditions (Figure 2). It includes 3 categories: 1) clinical gingival health,[6,8,16] 2) gingivitis,[6,9,17] and 3) periodontitis.[6,11] Both clinical gingival health and gingivitis can occur on an intact periodontium, reduced periodontium in a non-periodontitis client, and reduced periodontium in a treated, stable periodontitis client. Periodontitis, by definition, could occur only on the reduced periodontium, and treated periodontitis clients who display the partial resolution of periodontal breakdown would be diagnosed with periodontal disease remission/control on a reduced periodontium. For simplicity of the diagram, other conditions proposed in the classification (such as periodontitis as a manifestation of systemic disease and peri-implant diseases and conditions) were excluded.

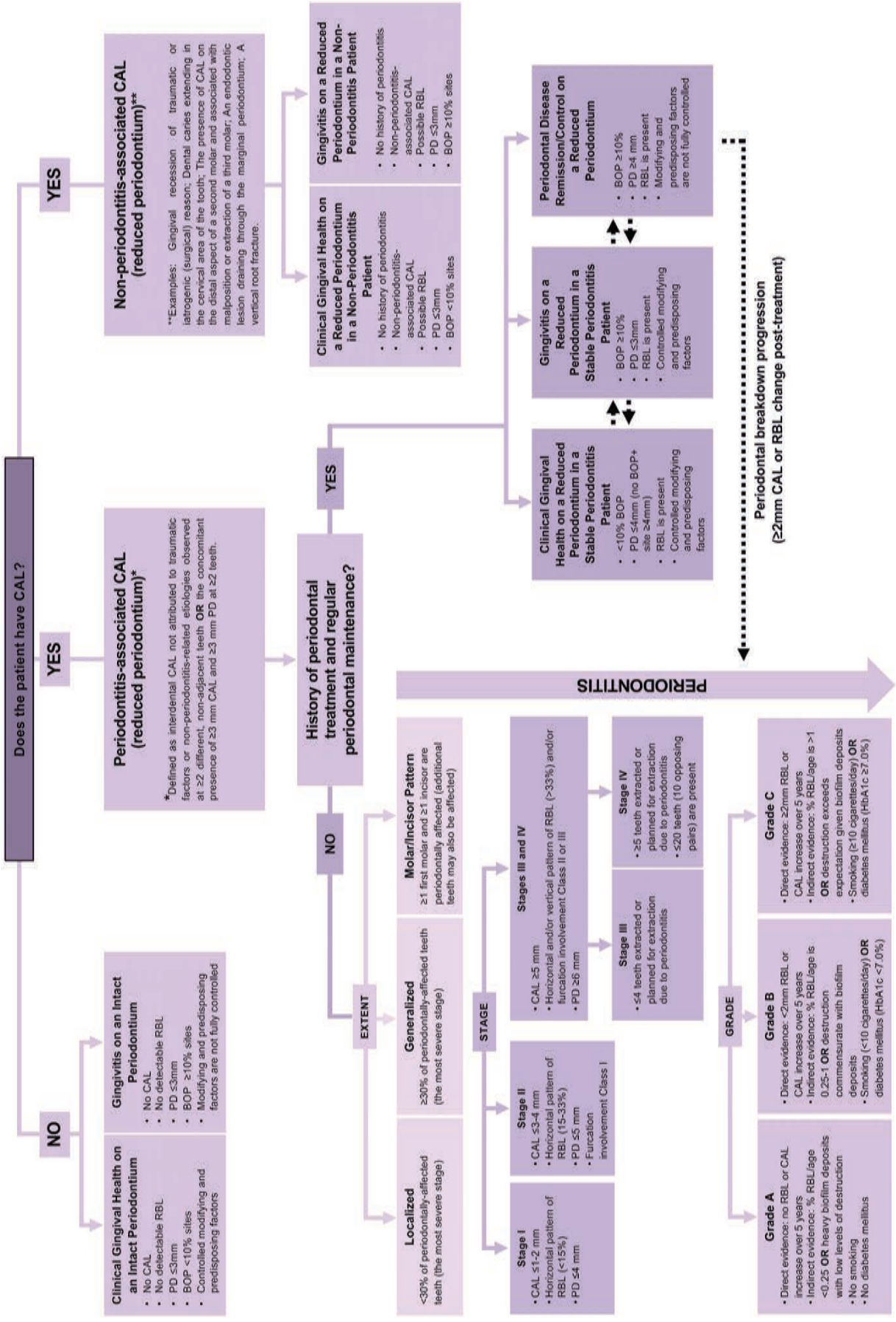
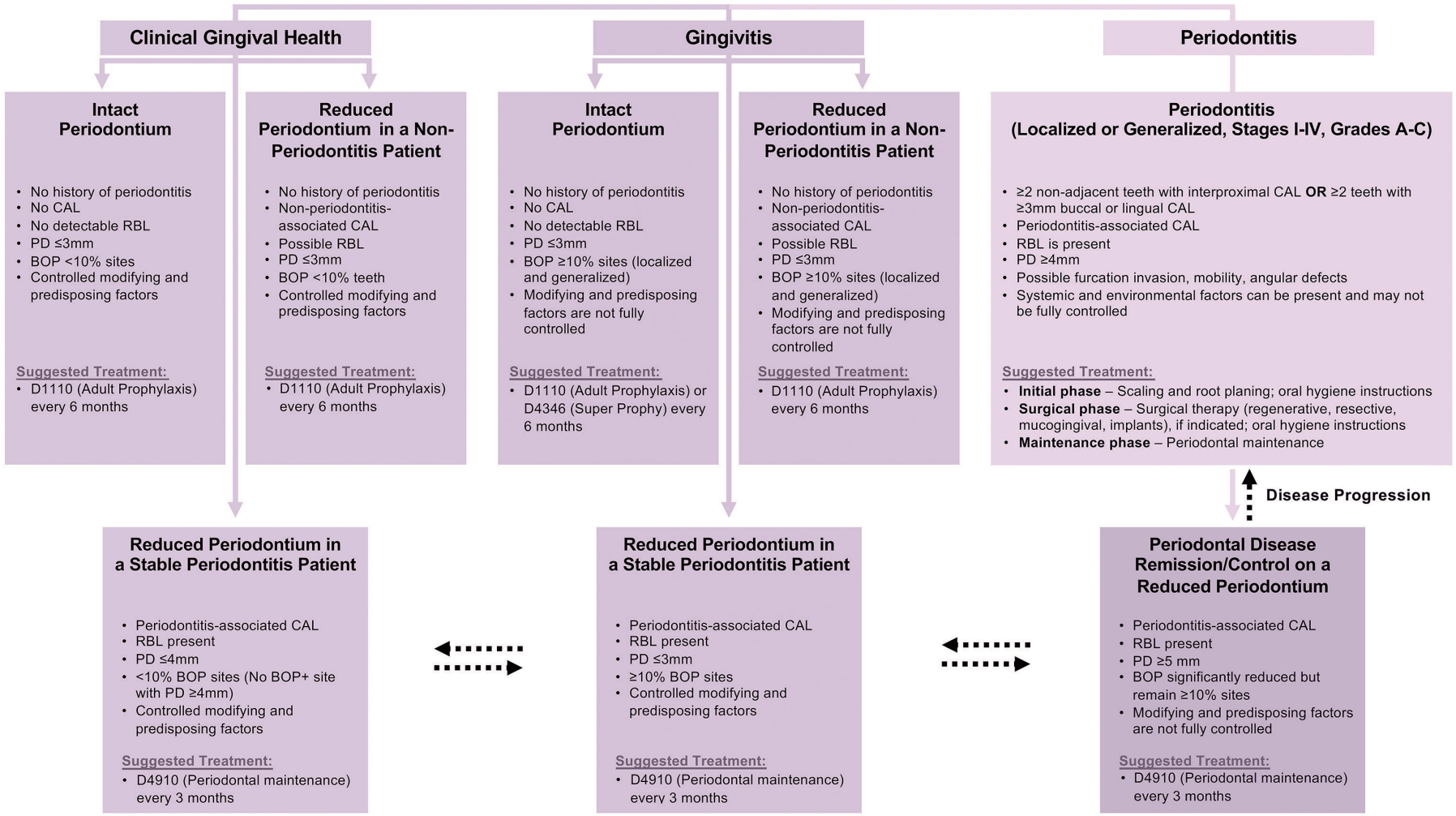


Figure 1. The decision-tree flowchart based on the 2017 Classification of Periodontal and Peri-Implant Diseases and Conditions

The flowchart includes clinical gingival health, biofilm-induced gingivitis, periodontitis, and outcomes of periodontal therapy. CAL: clinical attachment loss; RBL: radiographic bone loss; PD: probing depth; BOP: bleeding on probing; SRP: scaling and root planing.

Figure 2. The disease entity-based flowchart based on the 2017 Classification of Periodontal and Peri-Implant Diseases and Conditions



Suggested therapeutic approaches are based on evidence in the literature and are not officially proposed by the 2017 World Workshop in Periodontics. CAL: clinical attachment loss; RBL: radiographic bone loss; PD: probing depth; BOP: bleeding on probing; SRP: scaling and root planing.

The AAP diplomate authors of the study (KP, SA, and NA) validated both flowcharts by reviewing them to determine 100% agreement. If the authors disagreed with any aspect of the flowcharts (such as diagnosis definitions and determinants and schematic outline), the referenced studies from the 2017 World Workshop in Periodontics were used to resolve the disagreement.

Study design, population, and ethics

This crossover study involved DS entering their second, third, and fourth year of training (DS2, DS3, and DS4, respectively) and DHS entering their second year of training (DHS2). First-year DS and DHS were excluded, as they were not taught the new classification prior to conducting the study and did not begin providing focused periodontitis care until the following year of their training. The Institutional Review Board of the University of Texas Health Science Center at Houston approved all experimental protocols proposed in the study (protocol #HSC-DB-19-0824).

Methodology

In June 2020, all DS2, DS3, and DS4 (102, 107, and 99 students, respectively; a total of 308 students) and 39 DHS2 received an online invitation to participate in the study with examination links generated specific to the year of training. The students were informed that participation in the study was voluntary and would have no effect on their grades. The consenting students took an online examination that consisted of 10 descriptive clinical periodontal cases (Table 2). The cases were developed by the authors of the study who agreed on the expected diagnosis prior to conducting the exam. The anonymised participants were asked to diagnose periodontal conditions using their curricula-based knowledge without any additional tools (control group). Immediately after the examination, the same students completed the second online examination, which consisted of the same clinical cases, but used the flowcharts as an additional aid (test group). All participants were proctored by ExamSoft (ExamSoft, Dallas, TX, USA) during the examination. The duration of each examination was recorded using ExamSoft's "Elapsed Time" feature that automatically calculated the time when the examination was started and completed. A single faculty member (KP) was responsible for collecting the examination responses and determining their accuracy. The accuracy of periodontal diagnosis served as the primary outcome of the study, and the duration of the mock examination served as the secondary outcome. Blinding was deemed impossible due to the crossover study design and because all participants were aware of the use of the flowchart. A single faculty member (KP) was responsible for collecting the questionnaire responses.

Table 2. Clinical cases presented during the online mock examination

Case description	Periodontal findings[a]	Diagnosis[b]
The 20-year-old patient presented with a chief complaint, "I came to have my teeth cleaned." Medical history was unremarkable.	• No history of periodontal therapy • Good oral hygiene with insignificant plaque and calculus deposits • No interdental CAL • No RBL • 1 mm to 3 mm PD • 7% BOP	Clinical gingival health on an intact periodontium
The 30-year-old patient presented with a chief complaint, "I need to have my 6-month dental cleaning." Medical history was unremarkable.	• No history of periodontal therapy • Excellent oral hygiene with minimal plaque and calculus deposits • 1 mm to 2 mm interdental CAL in the form of the gingival recession of traumatic (non-inflammatory) origin • 10% RBL • 1 mm to 2 mm PD • 5% BOP	Clinical gingival health on a reduced periodontium
The 45-year-old patient presented with a chief complaint, "I have bleeding gums, and my teeth are getting loose." Medical history was unremarkable.	• No history of periodontal therapy • Fair oral hygiene with abundant plaque and calculus deposits • 5 mm to 6 mm interdental CAL on 27% of teeth throughout the dentition. No data on the progression of CAL over time are available • 25% RBL • 5 mm to 8 mm PD • 82% BOP • 3 teeth were extracted due to periodontitis by the patient's local dentist	Localized periodontitis stage III grade B
The 46-year-old patient presented to you with a chief complaint, "I want you to check my gums and teeth." Medical history was unremarkable.	• You performed SRP on 7 mm to 8 mm PDs and then saw the patient for periodontal maintenance every 3 months for the next 1.5 years • Fair oral hygiene with some plaque and calculus deposits • 1 mm to 2 mm interdental CAL with no progression beyond the re-evaluation levels • 5 mm to 6 mm PD • 35% BOP	Periodontal disease remission/ control on a reduced periodontium

Table 2. *continued*

Case description	Periodontal findings[a]	Diagnosis[b]
The 55-year-old patient presented with a chief complaint, "I had gum treatment recently, and I'm here for my 3-month cleaning." Medical history was unremarkable.	• History of periodontal therapy (SRP and periodontal flap surgery) • Fair-to-poor oral hygiene • RBL and CAL around several teeth • 5 mm PDs **Therapeutic outcomes:** • During the next 2 years, you performed periodontal maintenance at a 3-month interval for this patient. Despite your best efforts, the patient had not improved his oral hygiene and his PDs and CAL increased up to 7 mm in 15% of the probing sites with the deepest radiographic bone defect reaching 60%.	Localized periodontitis stage III grade C
The 65-year-old patient presented with a chief complaint, "I want to save my remaining teeth." The patient reported type 2 diabetes mellitus (most recent A1C was 8.3) and a history of smoking 1 pack/day for the past 5 years.	• History of periodontal therapy (SRP) and periodontal maintenance 5 years ago. Since then, CAL changed by 2 mm to 3 mm in 40% of his teeth throughout the dentition. • Poor oral hygiene with significant plaque and calculus deposits • 5 mm to 6 mm interdental CAL • 50% RBL • 6 mm to 7 mm PD • 27% BOP • 5 teeth were extracted due to periodontitis by his local dentist	Generalized periodontitis stage IV grade C
The 40-year-old patient presented with a chief complaint, "I want you to check my gums." Medical history was unremarkable.	• History of periodontal therapy and regular periodontal maintenance 10 years ago. No major changes in periodontal health since then • Good oral hygiene with insignificant dental biofilm and calculus deposits • 1 mm to 2 mm interdental CAL due to previous periodontal treatment • 10% RBL • 2 mm to 3 mm PD • 15% BOP	Gingivitis on a reduced periodontium in a stable periodontitis patient
The 35-year-old patient presented with a chief complaint, "I came to have my teeth cleaned." Medical history was unremarkable.	• No history of periodontal therapy • Good oral hygiene with some plaque and calculus deposits • No necrotizing gingival and oral mucosa changes • No interdental CAL • No RBL • 1 mm to 3 mm PD • 26% BOP	Localized biofilm-induced gingivitis on an intact periodontium
A 22-year-old African American patient presented with a chief complaint, "I am concerned about some of my teeth, as they are getting looser." Medical history was unremarkable.	• No history of periodontal therapy • Good oral hygiene with insignificant amounts of biofilm and calculus • Up to 7 mm PD around teeth #2, 3, 8, and 19 • Up to 5 mm CAL around teeth #2, 3, 8, and 19 • Up to 40% radiographic bone loss around teeth #2, 3, 8, and 19	Molar-incisor pattern periodontitis stage III grade C
A 50-year-old patient presented with a chief complaint, "I want to have my gums checked to make sure they are healthy." Medical history was unremarkable.	• No history of periodontal therapy • Fair oral hygiene with no gross plaque and calculus deposits • 3 mm to 4 mm interdental CAL on 20% of teeth throughout the dentition. You do not have any data on the progression of CAL over time • 20% RBL • Up to 5 mm PD • 47% BOP	Localized periodontitis stage II grade B

[a]CAL: clinical attachment loss; RBL: radiographic bone loss; PD: probing depth; BOP: bleeding on probing; SRP: scaling and root planing.
[b]The correct answers are shown in the table for demonstration purposes and were not displayed anywhere during the examination.

At the end of each examination, a 5-point Likert scale was used to evaluate the participants' response to the optional question, "How difficult do you find the 2017 Classification of Periodontal and Peri-Implant Diseases and Conditions?" with and without the flowchart. Possible answers were "very easy," "easy," "moderate," "difficult," and "very difficult."

Null hypothesis

The null hypothesis stated that the use of the flowcharts did not have statistically significant effects on the accuracy and speed of diagnosing periodontal conditions.

Power calculation

Power analysis was performed using Stata/MP 17 software

(StataCorp, College Station, TX USA). It was determined that, for the comparison of group means to a reference value (including standard deviation), a sample size of at least 20 participants was required to achieve 80% power (0.05 significance level).

Statistical analysis

Statistical analysis was performed using GraphPad Prism 9 (GraphPad Software, San Diego, CA, USA). The comparison between control and test groups within the same class (DS2, DS3, DS4, and DHS2) was performed using a parametric paired 2-tailed test of significance. The comparison within the respective control and test groups (DS2, DS3, DS4, and DHS2) was performed using 1-way analysis of variance with a Holm-Šídák multiple comparisons test. The null hypothesis was rejected when the p value was ≤ 0.05. The word "significant" throughout the analysis of the results refers to statistical significance.

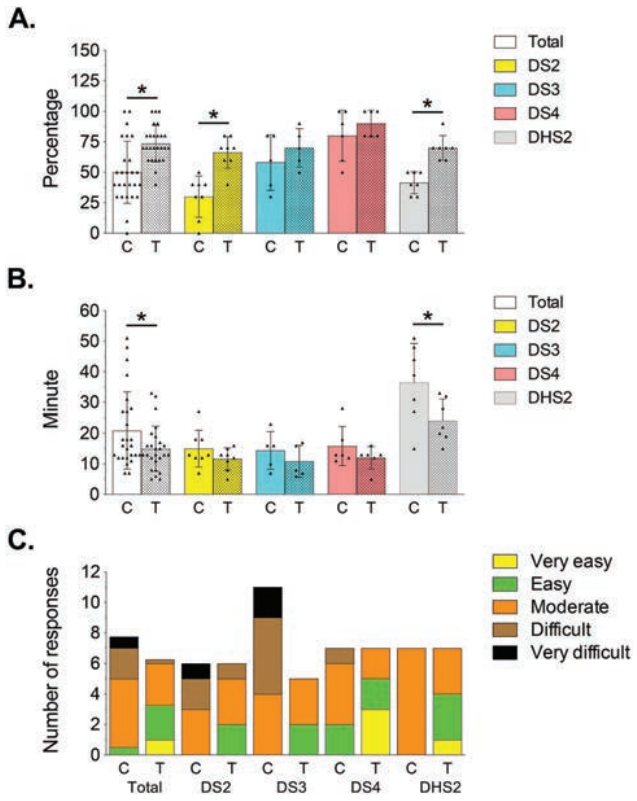
RESULTS

A total of 26 students (8 DS2, 5 DS3, 6 DS4, and 7 DHS2; 7.5% overall response rate) participated in the study. Figure 3A shows that, in all groups (DS2, DS3, DS4, and DHS2), the use of flowcharts was associated with increased accuracy of periodontal diagnosis compared to the respective controls (73.5% vs 50.0%, respectively; 1.47-fold; $p < 0.001$). The most substantial and statistically significant increases were observed in the classes of DS2 (66.3% vs 30%, respectively; 2.2-fold; $p < 0.001$) and DHS2 (70.0% vs 41.4%, respectively; 1.7-fold; $p = 0.002$), whereas DS3 (70% vs 58%, respectively; 1.2-fold; $p = 0.46$) and DS4 (90% vs 80%, respectively; 1.1-fold; $p = 0.28$) had more modest and statistically insignificant increases. The accuracy of periodontal diagnosis in control and test DS groups was significantly associated with the increased year of training ($p < 0.001$ and $p < 0.01$, respectively). The accuracy of periodontal diagnosis was significantly higher in the control DS2 group but not the test DS2 group compared to the respective DHS2 groups ($p = 0.025$ and $p = 0.53$, respectively).

Figure 3B shows that, in all groups (DS2, DS3, DS4, and DHS2), the use of flowcharts was associated with a significantly decreased duration of the examination compared to control (20.85 minutes vs 14.92 minutes (min), respectively; ~1.4-fold; $p < 0.001$). The extent of these decreases was similar in all DS groups compared to the respective controls; specifically, for DS2 (11.6 min vs 15 min, respectively; 1.29-fold; $p = 0.20$), DS3 (10.8 min vs 14.4 min, respectively; 1.33-fold; $p = 0.43$), and DS4 (12.0 min vs 15.8 min, respectively; 1.32-fold; $p = 0.22$). There were no statistically significant associations between the duration of the examination and the year of training in both control and test DS groups ($p = 0.93$ and $p = 0.89$, respectively). The use of the flowcharts was also associated with a significant decrease in the duration of the examination only for DHS2 (24.1 min vs 36.4 min, respectively; 1.51-fold; $p = 0.01$). The duration of the mock examination was significantly shorter in both control and test DS2 groups compared to the respective DHS2 groups ($p = 0.004$ and $p = 0.019$, respectively).

Figure 3C shows the participants' optional comments in response to the question, "How difficult do you find the 2017 Classification of Periodontal and Peri-Implant Diseases and Conditions?" The flowchart appeared to make the comprehension of the 2017 classification easier and more straightforward for students of all years of training. Table 3 shows optional, unedited feedback from the participants on the use of the flowcharts. The students noted that, although they found the flowcharts to be simple and helpful, their layout could be improved further. Interestingly, several students also proposed that the use of a similar decision-tree-based software application would make diagnosing periodontal conditions even more straightforward.

Figure 3. The effects of the flowcharts on the accuracy of periodontal diagnosis (A), the duration of the mock examination (B), and the feedback of students on the difficulty of the periodontal classification (C)



Graphs A and B: Results represent mean ± standard deviation (SD). The asterisk represents the statistical significance defined by the p value ≤ 0.05. **Graphs A, B, and C**: C = control; T = test.

DISCUSSION

The 2017 periodontal classification, including updated concepts of clinical gingival health, gingivitis, and periodontitis, was implemented into the curricula of the

Table 3. Student feedback on the use of the flowcharts

Positive feedback	Constructive criticism	Suggestions
1. "These flowcharts are clear and concise. Very helpful! They put all of the information we learned together in one place and greatly reduced the complexities of diagnosis of periodontal conditions."	1. "The flowchart is very easy to use and follow along. The only thing that makes it difficult is the amount of text in each text box."	1. "It would be greater if there is a software format or app where clinicians do several clicks based on some questions provided (e.g., clinical attachment loss –> yes or no) in the app, in which it gives the final diagnosis."
2. "The questions were reasonable and accurately represented what you would be presented within the clinic."	2. "Teaching the rationale for and definitions included in it is helpful, but I still found the diagnosis of treated periodontitis patients challenging, especially if treatment was performed a long time ago and a patient was not maintained properly since then."	2. "It would be helpful if the charts were integrated into dental software like axiUm and other sources."
3. "The flowchart makes me able to confidently diagnose periodontal conditions. Without them, I tend to misdiagnose several conditions. They have made clinical diagnosis very swift and became much more easily memorized than the original document."		

institutional undergraduate dental and dental hygiene courses in summer 2018. DS2 and DHS2 were taught the updated periodontal classification during their introductory periodontics course in spring/summer 2020. Since the students had not started their clinical training before the study was conducted, they were not able to practise the revised classification system in a clinical learning environment. Both DS3 and DS4 were taught the updated periodontal classification during the introductory periodontics course in summer 2018 and have applied and enhanced their knowledge of the classification chairside since then. Therefore, DS2 and DHS2 had a similar but more limited amount of time to memorize the updated classification and exercise their curricula-based knowledge compared to both DS3 and DS4. Student knowledge was evaluated through formative assessment methods, and they were further evaluated on their application of knowledge through their respective clinical courses.

In addition, the new disease entities were added to the university's axiUm® dental software (Henry Schein, Melville, NY, USA), and students were required to diagnose periodontal conditions using these updated entities in their daily clinical cases and competency examinations. Therefore, the ability of students to comprehend the 2017 classification became an important factor that determined their didactic performance and appropriate client care (including diagnosis-driven treatment selection).

The current study proposed the use of straightforward schematics to increase the accuracy of periodontal diagnosis made by DS and DHS. This study focused on these groups of trainees since they were actively treating clients with periodontitis but had more limited knowledge and depth of experience in periodontics compared to experienced periodontists and dental hygienists. Among control DS, the diagnostic accuracy was the lowest among DS2 and significantly increased with advanced years of training. However, even the DS2 had a significantly higher accuracy of periodontal diagnosis compared to the DHS2 class. When the flowcharts were used, the diagnostic accuracy significantly increased with advanced years of DS training, but the greatest extent of increases was seen in the DS2 class (2.2-fold) followed by DS3 and DS4 (up to 1.23-fold). Although only second-year DHS participated in the examination, the increases in their diagnostic accuracy were relatively comparable to that of DS2 (1.7-fold). Interestingly, in contrast to control groups, the respective DS2 and DHS2 groups had a similar accuracy of periodontal diagnosis. These results demonstrate that the flowcharts could be particularly useful to those individuals with limited experience in using the 2017 classification.

In both control and test DS groups, no statistically significant associations between the duration of the examination and the year of training were observed. At the same time, compared to control, the use of the flowcharts significantly decreased the duration of time to complete the examination (~1.4-fold). However, when stratified based on the class, only test DHS2 had significant decreases as compared to control (~1.51-fold), but when compared to test DS2, their examination time was significantly longer. Overall, these results suggest that all DS worked through the flowcharts and determined an accurate diagnostic path irrespective of their year of training, but DHS2 took a longer time to complete these tasks.

The results also show that, not only did DS and DHS diagnose periodontal conditions faster using the flowcharts, but they also improved their comprehension of the 2017 classification. Overall, the participating students provided positive and encouraging feedback. However, a few critical points were highlighted, which will be used to further improve the flowcharts. For example, the participants noted that they still found the classification of previously treated periodontal clients challenging, especially when

the treatment was performed a long time ago without proper periodontal maintenance. In addition, they noted that, once the flowcharts included multiple conditions, they became more challenging to follow. Interestingly, several students also suggested providing the flowcharts in the form of application software that could automate the diagnosis process and possibly become an integral part of the dental electronic health record software. This study's authors have developed such software and are currently testing its accuracy in clinical settings.

Although the current classification was introduced several years ago, only a few studies have published illustrative charts to diagnose periodontal conditions in a more time- and effort-effective manner. Tonetti and Sanz[20] developed a comprehensive decision-tree approach that followed the AAP/EFP diagnostic determinants (including CAL, RBL, PD, and BOP) to distinguish between various gingival and periodontal conditions and accurately determine the stage and grade of periodontitis. However, clinical scenarios of treated clients with periodontitis (periodontal stability, remission/control, and "reactivation" of periodontitis due to unsuccessful periodontal treatment) remained unaddressed. Recently, Sutthiboonyapan and colleagues[21] also proposed the use of a flowchart to simplify periodontal diagnosis. However, it used PD as an initial diagnostic criterion for gingival conditions. In contrast, the present study proposed using CAL as the primary diagnostic criterion, according to the guidelines outlined by the AAP and EFP. The Sutthiboonyapan et al. study[21] was also primarily focused on the step-by-step diagnosis of periodontitis (including the stages and grades). However, similar to Tonetti and Sanz's study, it did not address the clinical scenarios of treated clients with periodontitis. In addition, both studies focused on the illustrative approach to diagnosing periodontal conditions, whereas the current study not only reported on the development of the flowcharts but also determined their impact on the accuracy and speed of periodontal diagnosis.

Limitations

This study had a lower-than-expected response rate from students, especially among DS. Despite several recruitment emails, those students showed modest interest in participating in the study, therefore increasing the risk of nonresponse bias. The low response rate justifies the need to conduct a large-scale study to ensure that the results of the present study are replicable. Nevertheless, the results of this pilot study are worth disseminating, as they show the feasibility of the flowcharts as an educational aid.

Second, the online mock examination included the same group of students who reviewed the questions twice—the first time without the flowchart and the second time with the flowchart. Therefore, the increased accuracy in diagnosing periodontal conditions and/or reduced duration of the examination could be at least, in part, a result of familiarity with the cases.

Third, this study responded to the students' feedback on avoiding excessively complicated charts and intentionally excluded local (e.g., dental prostheses, overhanging restorations, and tooth crowding), systemic (e.g., obesity and rheumatoid arthritis), and other contributory factors (e.g., traumatic occlusal forces, periodontal-endodontic lesions, abscesses, necrotizing soft tissue changes, systemic conditions affecting periodontal supporting tissues, various types of gingivitis, mucogingival conditions, and peri-implant conditions), as well as a distinction between localized and generalized conditions. To rectify these omissions and to address the students' suggestions for the development of an automated diagnostic tool, the authors of the study have developed and are currently testing application software that includes the entire spectrum of periodontal conditions, allowing for their comprehensive and accurate diagnosis.

Fourth, because the students took both examinations online, the efficiency of the flowcharts used chairside needs to be further explored.

Finally, since the study was performed in academic settings, the importance of its outcomes in non-academic settings (such as private practices) is unknown.

CONCLUSION

This study reported on the development of illustrative flowcharts, which consisted of several straightforward questions and answers leading to the suggested periodontal diagnosis of clinical gingival (periodontal) health, biofilm-induced gingivitis, periodontitis, and outcomes of periodontitis therapy. When tested among DS and DHS, the flowcharts significantly improved the accuracy of periodontal diagnosis in a time-efficient manner, especially among individuals with limited periodontal experience. The developed flowcharts may be used by DS, DHS, and dental faculty in academic settings to ensure a more accurate and time-effective diagnosis of periodontal conditions based on the 2017 classification.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Gordon Finnerty Jr for his excellent technical support with organizing online examinations on the ExamSoft platform. The study was funded by the Dean's Academy Small Grants Program.

CONFLICTS OF INTEREST

The authors have declared no conflicts of interest associated with the study.

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