Classification and prognosis evaluation of individual teeth—A comprehensive approach

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Following a complete evaluation of the patient, treatment planning requires the analysis of individual teeth, accurate diagnosis, and prognosis evaluation. Currently, there is no accepted comprehensive, standardized, and meaningful classification system for the evaluation of individual teeth that offers a common language for dental professionals. A search was conducted reviewing existing literature relating to classification and prognostication of individual teeth. The dimensions determined to be of importance to gain an overall perspective of the individual relative tooth prognosis were the periodontal, restorative, endodontic, and occlusal plane perspectives. The authors present a comprehensive classification system by conjugating the literature and currently accepted concepts in dentistry. This easy-to-use system assesses the condition of individual teeth and enables a relative prognostic value to be attached to those teeth based on tooth condition and patient-level factors. *(Quintessence Int 2009;40:377–387)*

Key words: classification, dental assessment, endodontic, diagnosis, occlusal plane, periodontic, prognosis, restorability, tooth, treatment planning

Currently there is no accepted standardized tool for assessing the overall status of teeth. Predicting whether a tooth is likely to be long-standing in the patient's mouth, making it appropriate to be part of the overall rehabilitation of a patient, is one of the most challenging tasks in dentistry. An accurate diagnosis and prognosis evaluation are the basis of solid treatment planning and are essential when treatment options are considered. The aim of this article is to propose a comprehensive, standardized, and meaningful classification system for the evaluation of individual teeth. The classification system enables a relative prognostic value to be attached to each evaluated tooth for treatment planning purposes.

The proposed classification aims to become a systematic tool that would enhance communication among dental professionals, be used for evaluation of cases from a medicolegal perspective, generate a baseline for outcome assessment of treatment modalities, and enable young and experienced clinicians alike to evaluate dental conditions in a uniform way. It could also facilitate patient understanding of the condition of their teeth, enabling them to make informed decisions before they consent to various treatment options.

Prognosis is defined as "a prediction of the probable course and outcome of a disease, and the likelihood of recovery from a disease."[1] However, evidence-based published data aimed at evaluating the relevance of clinical and radiographic findings as predictors for long-term prognosis are lacking in the dental literature.[2,3]

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Being aware of the complexities and limitations of any tool that aims to attach prognostic values to teeth, the authors used a "Delphi method" process[4,5] to receive input and feedback from clinicians and specialists from various backgrounds. This enabled the proposed classification to be based on both evidence-based data, whenever available, and commonly accepted best practices of the profession.

REVIEW OF CURRENT LITERATURE

Current literature does not present sufficient evidence to enable clinicians to attach an absolute prognostic value to individual teeth. The difficulty in attaching a prognostic value to individual teeth and predicting their survival has been well-documented.[2,6–8] In the age of evidence-based dentistry, clinicians strive to reach decisions made on sound scientific research. In the periodontal literature, the search for clinical and radiographic markers that can accurately predict tooth loss has proven to be quite limited.[8–11] In the restorative literature, very few attempts have been made to make such predictions. Previously published articles look at the longevity of varioous types of restorations[12–15] and the question of when to consider one treatment option for a particular tooth over another.[16–18] However, these articles focus on the success of the procedures or the success of a particular restorative type rather than on the tooth itself.

The difficulty is enhanced by the fact that multiple factors may influence the prognosis of teeth. These include certain diseases and systemic conditions that affect tooth prognosis, the patient's motivation for treatment and maintenance of oral health, the quality of treatment rendered, etc. For these reasons, the goal of this classification is not to determine an absolute prognostic value for individual teeth, but rather to attach a **relative prognostic value**, which aims to enable clinicians to distinguish between favorable teeth and those that are compromised to a certain degree.

Periodontal literature

Most of the attempts to attach a classification for the prognosis of individual teeth come from the periodontal literature. The traditional systems were based on tooth mortality[19] and did not look at the possibility of classifying a tooth's prognosis, based on the ability to control the disease process and successfully maintain the tooth as a working unit in the dentition. In general, these studies look at whether a tooth "survived," and not whether it would be appropriate to be included into a restorative-treatment plan.

In 1978, a 22-year retrospective study by Hirschfeld and Wasserman[20] looked at 600 patients and compared prognosis of "favorable" and "questionable" to actual tooth loss in patients that had similar periodontal conditions and underwent similar treatments. Teeth considered questionable were those with deep probing depths, furcation involvement, bone loss, and mobility. Although deep probing depth is still considered a good indicator of the presence of active periodontal disease, furcation involvement and bone loss more accurately indicate past disease. Similarly, mobility may be related to occlusal factors and therefore is not a reliable indicator of the presence of active periodontal disease.[21]

In 1984, Becker et al[22,23] looked at the influence that a strict periodontal maintenance program had on tooth loss. Prognostic categories of "good," "questionable," and "hopeless" were used. Teeth with a least one of the following—50% bone loss, 6- to 8-mm probing depth, Class 2 furcation, or anatomic variables such as a deep palatal groove on the maxillary incisors or a mesial furcation involvement of the maxillary first premolar—were classified as questionable. Teeth with more than one of the following—more than 75% bone loss, more than 8-mm probing depth, Class 3 furcation involvement, Class 3 mobility, poor crown-root ratio, unfavorable root proximity, or repeated periodontal abscess formation—were considered hopeless. This study showed that it was possible to accurately predict chances of tooth survival in a well-maintained group, but those that were not well-maintained were not as predictable. In the well-maintained group, the

disease process was controlled, whereas in the nonmaintained group, the above-mentioned factors were not all indicators of disease activity. Hence, these factors may not have been accurate at predicting disease progression. The study illustrates how periodontal maintenance and patient compliance influence long-term prognosis.

In the 1990s, McGuire and Nunn documented a series of papers based on a longitudinal investigation that followed 100 patients at 5, 8, and 15 years. The system categorized teeth as "good," "fair," "poor," "questionable," and "hopeless." Their first 2 studies,[9,10] similar to previously published articles, based the assessment of prognosis on commonly accepted clinical findings such as probing depth, bone loss, furcation involvement, mobility, crown-root ratio, and root form, and concluded that these clinical parameters were ineffective at predicting any outcome other than "good." The third article[11] evaluated the relationship of the above clinical parameters to tooth loss. They concluded that although there is a relationship between prognosis and tooth loss, initial prognosis did not adequately predict tooth survival. This led them to their fourth and final article,[24] in which they began looking at host susceptibility as a further influencing factor. From this study, it seems that host factors such as the presence of interleukin-1 genotype improved the accuracy of predicting tooth loss, as did smoking.

In 2006, Muzzi et al[8] directed a 10-year retrospective study to evaluate the ability of clinical, radiographic, and genetic variables to accurately predict tooth loss in a population undergoing a strict maintenance regimen. They concluded that the infrabony component of the defect and the amount of residual bone may be good prognostic factors for predicting tooth loss; however, more traditional methods were proven to be of little value.

More recently, an attempt to classify prognosis by the ability, or inability, to achieve periodontal stability was made.[19] Periodontal stability can be monitored by routine clinical examinations and radiographs, and this system aims to help clinicians make decisions for treatment planning and patient management rather than just looking at the relationship of initial prognosis to tooth mortality as is done in previous systems.[19] Furthermore, the need to differentiate between individual tooth prognosis and overall prognosis for the patient is recognized. Kwok and Caton's[19] system focuses on only periodontal factors, although it gives consideration to both local and systemic risk factors, which need to be reassessed over time.

Restorative literature

The restorative literature includes effective classification systems, but lacks a classification system that gives clinicians a tool to assess the condition and the prognostic value of individual teeth. It has been widely documented that the key to long-term success in the restoration of endodontically treated teeth is directly related to the amount of remaining sound coronal tooth structure.[25–31] A recent systematic review[25] concluded that the most critical aspect when dealing with a nonvital tooth is "tissue preservation." Similarly, the importance of providing an adequate ferrule is generally accepted.[25,27,29] Thus, the amount of remaining sound tooth structure should be considered key in assessing restorability.[30,31]

Few attempts have been made to create an index that measures actual remaining coronal dentin or grades tooth restorability. The main problem with the development of such an index lies in the need to assess actual remaining sound tooth structure before actual caries removal. Bandlish et al[32] took 20 teeth, produced casts, and derived a technique to assess the amount of remaining dentin present after crown preparation. A tooth restorability index was developed to assess the strategic value of the remaining dentin. This divided the teeth into sextants, and a score of 0 to 3 was attributed whether the amount of remaining dentin was "none," "inadequate," "questionable," or "adequate," such that a maximum of 18 could be scored for each tooth. The 20 teeth were analyzed by 3 experienced dentists, who used the combined cast of remaining coronal dentin to score the tooth restorability index for each tooth. This study concluded that the suggested system provided "moderate to good"

agreement among the examiners and suggested that it was a good way of assessing restorability of a tooth.

No other articles included for review attempted to produce a quantitative system to assess how much tooth structure remains. Other attempts at assessing restorability[33] are less didactic and avoid quantification, leaving a nonprecise, subjective assessment as to how much remaining tooth structure is enough to make a tooth restorable.

Endodontic literature

The endodontic prognosis of a tooth in isolation of the other categories is largely linked to the difficulty of the case at hand.[34] Potential problems include calcifications, inability to isolate the tooth, resorptive defects, extra roots and/or canals, retreatment cases, existing posts, ledges, and perforations. Many different guides have been compiled to help clinicians determine the degree of treatment difficulty for a given case. These include the UCSF (University of California, San Francisco) Endodontic Case Selection System, guidelines put out by the American Association of Endodontics, the Canadian Academy of Endodontics, and the Dutch Endodontic Treatment Index.[35] The other factor influencing the endodontic prognosis is the presence of a periapical radiolucency. Clinical trials have shown a lower success rate in endodontic cases with periapical radiolucencies because the causative pathology has been present for a longer period.[36] The ability to determine the cause of a radiolucency is key to understanding if a root canal can be predictably treated.

A strong association has been noted between the crowning of endodontically treated teeth and their long-term survival.[37–41] This emphasizes the closely intertwined relationship between endodontic and restorative prognosis. It is commonly stated that endodontic therapy is not complete until a coronal restoration has been placed,[42–44] and that the coronal seal is at least as important, if not more important, than the apical seal when looking at the long-term success of endodontically treated teeth.[37,42–45]

Literature related to the occlusal plane

No literature was found to measure the degree of super-eruption or amount of tooth tipping within an arch that determines at what point a tooth becomes nonsalvageable or inappropriate for inclusion in a restorative treatment plan. However, current accepted concepts[30,31,46] suggest that it is beneficial to restore teeth to the correct occlusal plane and that over-erupted and tilted teeth can potentially prevent normal tooth contact during function and therefore require treatment.[47–49] In partly edentulous patients, such teeth may create a problem when restoring the opposing arch.[50] The scope of potential treatment ranges from enameloplasty or orthodontic treatment to extraction of severely tilted or over-erupted teeth.[51] Moderate cases may require a partial or a full-coverage restoration. However, some cases may require a combination of endodontic treatment, crown-lengthening surgery, and a restoration to achieve a functional tooth that lies correctly within the occlusal plane. Special attention is required when analyzing these cases, since such procedures may result in a tooth that has an unfavorable crown-root ratio, and in certain cases may cause periodontal damage to itself and/or to neighboring teeth.[21,30,31] Aggressive surgical procedures in which segments of the maxilla or the mandible are shifted from their original position have also been published; however, since these treatment modalities are not readily available, they are excluded from this classification.

RATIONALE OF THE PROPOSED CLASSIFICATION SYSTEM

There are many types of classification system. Simple but powerful classifications like Angle's classification and the Kennedy classification have been used in dentistry for decades. This proposed classification system similarly aims to be simple while being comprehensive, standardized, and meaningful.

It does not aim to allow for perfect differentiation among all potential situations. Rather, it includes those criteria that generally make a significant impact on the condition of a specific tooth and therefore on its relative prognostic value.

An assumption is made that current accepted dental standards and best practices will be employed to treat the diagnoses.

Dental patient evaluation involves 2 sequential phases. The first phase takes patient-level considerations into account, and a second phase aims to classify individual teeth.

Patient-level considerations

Multiple patient-level factors play a significant role in the prognosis of teeth. These can be divided into 3 main categories: biologic risks, environmental risks, and financial and behavioral/personal risks (Table 1). A fourth significant factor relates to the quality of the dental treatment and the frequency and quality of oral health maintenance. Each of these categories affects the progression of the disease, be it periodontal disease, caries, malocclusion, etc, and will influence the likelihood of recovery.

The number of risk factors present and their severity will determine the extent of their impact, as will the ability to modify and/or eliminate the risk factors. In general, risk factors that are associated with high caries rate and periodontal disease are those that will challenge prognosis evaluation. These can be best assessed by the various caries risk assessment (CAMBRA [caries management by risk assessment])[52–56] and periodontal risk assessment[57,58] tools available. Such tools categorize patients into high, medium, or low risk groups, and management can be customized to control disease progression. Conditions that increase patient risk for caries—dry mouth, diet, habits, hygiene, unfavorable microflora, root exposure, and limited fluoride exposure—and factors that may result in future deterioration of the periodontal apparatus—oral hygiene, metabolic/systemic disease, unfavorable microflora, family history, smoking, age, and existing periodontal disease—potentially increase the patient's likelihood of further disease progression.

Table 1 Examples of patient-level risk factors

Biologic risk factors
Medical conditions that impair immune function and healing
Impaired salivary flow/function
Medical condition or disability limiting oral hygiene
High *Streptococcus mutans* and *Lactobacillus* salivary count
Positive for interleukin-1 genotype
Family history
Other missing teeth
Behavioral risk factors
Compromised or poor oral hygiene
Cariogenic diet
Low exposure to fluoride
Parafunctional habits
Ability and willingness to adhere to a long-term maintenance protocol
Smoking
Financial/personal risk factors
Motivation for treatment
Available resources for dental care
Willingness to commit finances, time, and effort
Attitude toward losing teeth
Understanding of one's condition and needed treatment
Esthetic expectations
Low dental IQ

Parafunction may also increase the risk to individual teeth or to the entire dentition.

Because only some risk factors can be diminished or even eliminated, these should be divided into modifiable and nonmodifiable risk factors. If modifiable risk factors are managed during and following treatment, overall tooth prognosis should be reassessed. An alert can be captured in the patient chart to emphasize the need for appropriate management. Such treatments aim to diminish patient likelihood of further disease progression often through lifestyle changes. However, those patients who have multiple nonmodifiable or unsuccessfully controlled risk factors display an overall inferior case prognosis. There are publications presenting long-term success of oral rehabilitation of compromised dentitions.[59–61] These are examples of how the prognosis evaluation of a tooth may be improved based on positive alterations of modifiable risk factors.

Financial constraints, as well as a patient's behavior and personal factors (level of motivation for treatment, adherence to maintenance care protocols, phobia, unwillingness

or inability to endure lengthy and involved procedures, refusing treatment, etc), may result in further deterioration. Therefore, they should also be factored into the overall relative prognosis of all teeth and will influence treatment decisions. Esthetic considerations play a significant role in a patient's treatment choice, although they do not alter tooth prognosis per se. In certain cases, these factors may bring about a decision to extract a tooth that otherwise could be saved.

Evaluation of individual teeth

Criteria for analysis. Four main criteria and 2 additional factors that may compromise these criteria are evaluated:

1. Periodontal condition and alveolar bone support
2. Restorability, ie, remaining sound tooth structure
3. Endodontic condition
4. Occlusal plane and tooth position

The 2 additional factors, which may compromise the above, are evaluated when applicable. These include:

1. Anatomic irregularities
2. Iatrogenic compromising factors

The classification rules. The proposed classification comprises 5 classes—A, B, C, D, and X—and requires 2 steps of analysis. An assumption is made that current accepted dental standards and best practices will be employed to treat the diagnoses.

Step 1. Each tooth is evaluated for each of the 4 criteria independently. The level of severity is evaluated both based on the presented condition and with consideration to the foreseen tooth status after caries removal. *The single most severe of these criteria determines the tooth's class* (Table 2).

Step 2. *Anatomic risk factors and/or iatrogenic compromising factors may result in a drop of a class for an individual tooth.* More than 2 such findings in a tooth may require a further drop in class (Table 3).

Step 3. *Patient-level risk factors* may result in a decreased prognosis for the dentition. Therefore, *a drop of 1 class for all teeth* is suggested when considerable patient-level risk factors are diagnosed. Patient-level risk factors are reassessed over time. A decrease in class should be considered when no change in modifiable risk factors is observed, or when significant nonmodifiable factors are present. An increase in class should be considered when an obvious change in modifiable risk factors is observed.

The system may be included into routine clinical examination and recorded on a periodontal and hard tissue chart. A suggestion is demonstrated based on the chart used at Harvard School of Dental Medicine (Fig 1).

DISCUSSION

Treatment planning is a multistage process that involves the analysis of each tooth from various aspects. Many of the diseases affecting the dental structures are bacterial or infectious in nature. Other etiologies may also cause the destruction of tooth and supporting structures. Any chosen treatment modality requires management and monitoring of the cause and of the disease process in addition to mechanical/surgical treatment, as well as the adherence to a long-term maintenance protocol.[59–61,69,70]

Based on the reviewed literature and accepted best practices, this proposal bases the classification of the condition of teeth and their relative prognosis on 4 main criteria and 2 additional factors. Patient-level factors may alter the overall prognosis of a case, especially when these factors cannot be modified by the patient or by treatment.

Periodontal status, endodontic status, tooth position, and iatrogenic and anatomic factors can be assessed based on clinical and radiographic indicators. Understanding of caries progression by using the CAMBRA protocol should help clinicians assess caries progression so a class can be determined. However, there may be cases in which the extent of tooth destruction by caries can only be accurately determined after mechanical removal.

Table 2	An evaluation of pathology and the scale of severity
Class A	A tooth in this category is one that is considered to have a **good** prognosis. Such a tooth is assumed to have minimal risk of being lost in the foreseen future.
Periodontal health and alveolar support	80% to 100% bone support. Can be easily maintained.
Remaining tooth structure	80% to 100% remaining sound coronal tooth structure. Can be easily restored.
Endodontic condition	A tooth that can receive a straightforward primary endodontic treatment, or already has good endodontic therapy.
Occlusal plane and tooth position	A tooth that is in the correct occlusal plane and/or position, or one that is slightly deviated from ideal and may require minimal enameloplasty.
Class B	A tooth in this category does not belong to Class A but has a **fair** prognosis such that treatment outcome is considered predictable. Such a tooth poses a low risk of being lost in the foreseen future.
Periodontal health and alveolar support	50% to 80% bone support, which can be well maintained with rigorous periodontal and maintenance therapy. Vertical defects or furcations that can be periodontally treated to become easily cleansable or treated predictably with regenerative therapy.[62] Molars are at higher risk than single-rooted teeth.[8,63]
Remaining tooth structure	50% to 80% remaining sound coronal tooth structure. Involved restorative procedures result in no infringement of biologic width, adequate ferrule,[26,27,34] or good crown-root ratio and would minimally affect adjacent structures (if at all).
Endodontic condition	A failing endodontic treatment with obvious causes of failure and that can be predictably retreated, Or a tooth that requires a difficult primary endodontic treatment.
Occlusal plane and tooth position	A tooth that is out of the occlusal plane and can be adjusted so that it functions within the correct occlusal plane. Such a tooth may require additional treatment to seal exposed dentin.
Class C	A tooth in this category is one that has one or more problems and can be treated and maintained, but its prognosis remains **questionable**. Such a tooth has a medium risk of being lost.
Periodontal health and alveolar support	30% to 50% remaining bone support. No ongoing acute outbreaks, but maintaining cleansability is difficult. Periodontal therapy and a thorough maintenance program will enable the tooth to be maintained for an acceptable period of time.[64]
Remaining tooth structure	30% to 50% remaining sound coronal tooth structure. Or a tooth with so little tooth structure that achieving adequate ferrule would result in compromising the crown-root ratio to some extent, and/or may affect adjacent structures.
Endodontic condition	An acute/chronic failing endodontic treatment that presents difficulty to predictably retreat.
Occlusal plane and tooth position	A tooth that is out of the occlusal plane and requires multiple procedures to function within the occlusal plane.
Class D	This category is for a **compromised** tooth that has a high risk of being lost. This includes those teeth that have no active pathologic conditions requiring immediate extraction, but it may not be in the patient's best interest to invest in such a tooth. Since there is no obvious indication for extraction, external factors influencing the overall case and patient factors will play a major role in determining how to approach such a tooth.
Periodontal health and alveolar support	A tooth with < 30% bone support, and/or one that cannot be cleansed or maintained well and has evidence of active periodontal disease.
Remaining tooth structure	A tooth with < 30% sound tooth structure, or one in which the extent of the lost tooth structure does not enable a good ferrule to be achieved without totally compromising the support of the adjacent tooth structures or crown-root ratio.
Endodontic condition	A tooth with a failing endodontic treatment that cannot predictably be retreated.
Occlusal plane and tooth position	A tooth so severely out of the occlusal plane or severely tilted that after extensive treatment will exhibit reduced crown-root ratio, which will prevent it from serving as a long-term unit in the arch. Or a tooth whose position impacts the health of the adjacent structures.
Class X	A tooth in this category is **nonsalvageable** and is indicated for extraction. Such teeth cannot be restored or present pathologies that currently dentistry does not have a solution for. These include teeth that may pose risk to the patient's health.
Periodontal health and alveolar support	A tooth with < 30% bone support and cannot be cleansed or maintained without acute outbreaks of periodontal infection.
Remaining tooth structure	No remaining supragingival sound coronal tooth structure.[65,66] Loss of tooth structure deep into the root dentin/canals.[30,67]
Endodontic condition	A vertical root fracture,[3,68] or a tooth that has been retreated several times endodontically and/or surgically without resolution.
Occlusal plane and tooth position	A tooth so far super-erupted or tilted out of the occlusal plane that it cannot be restored into correct function, or would interfere with the restoration of that arch or the restoration of the opposing arch.

Table 3	Factors that result in a drop of the determined class
	Examples of findings that may compromise tooth relative prognosis
Anatomic irregularities	Irregularly shaped roots, multiple canals and/or roots, thin and/or short roots, and excessively conical roots cause a drop in the prognosis and increase the risk to that tooth.[30,31] This can often render a tooth with an otherwise fair or poor prognosis as critical or hopeless.
Iatrogenic compromising factors	Perforations, extensive post preparations, minimal tooth structure thickness left after preparation, dental materials that cannot be removed, etc. Without evidence of active pathology, the prognosis of a tooth with iatrogenic dentistry may even be fair or good; however, if further treatment is planned or the tooth is found with other pathology or clinical or radiographic signs and symptoms, the prognosis level drops.[30,31] In some cases, the tooth may even be indicated for extraction.

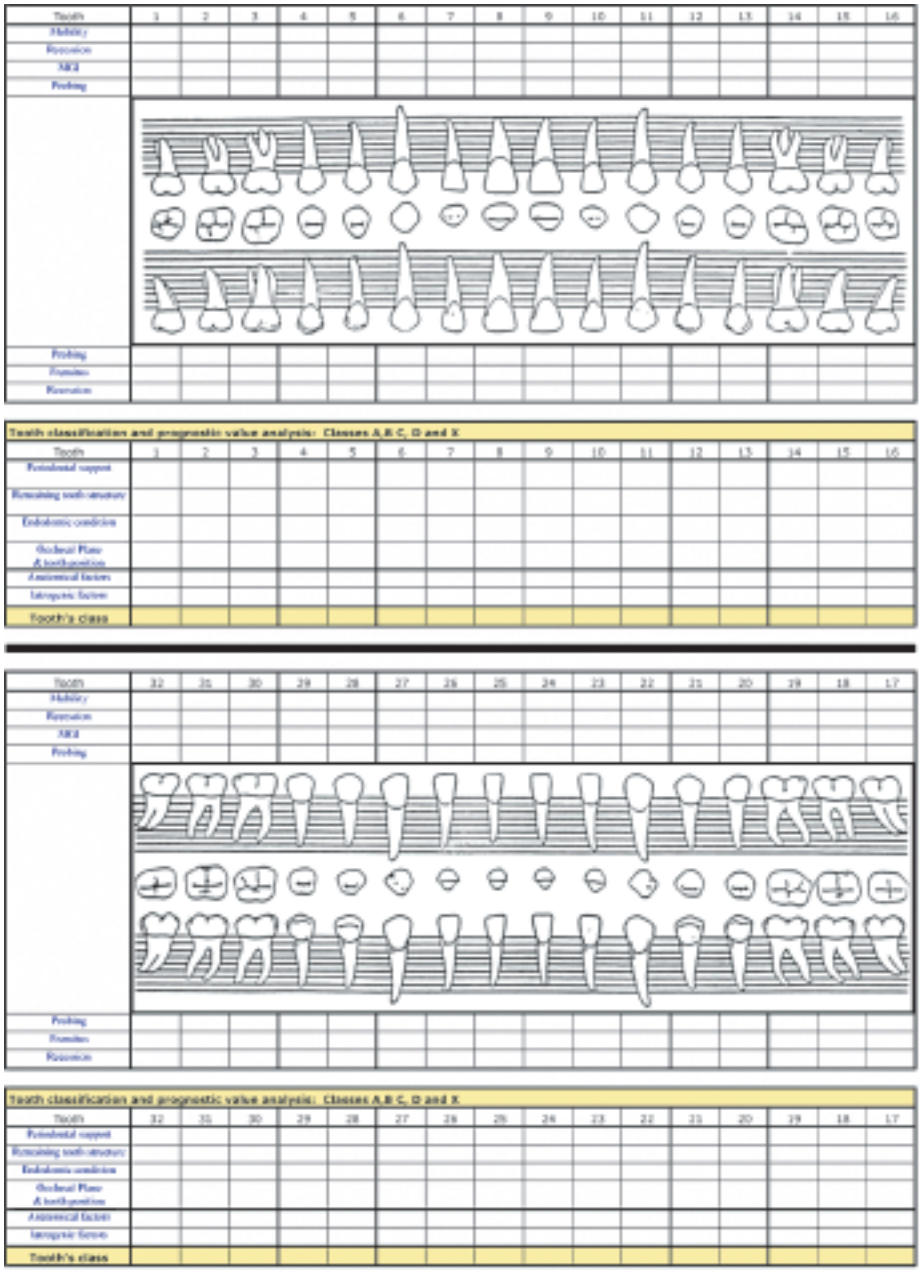

Fig 1 A proposal for the incorporation of individual tooth analysis into a conventional periodontal and hard tissue chart.

The proposed classification system aims to help clinicians in the treatment planning process, by focusing on individual and overall prognostic value of teeth. Thus, if a tooth that was originally planned to serve as an abutment for a prosthetic unit is found to be a questionable tooth (Class C) or a compromised tooth (Class D), an alternative treatment plan should be considered. On the other hand, if these teeth were supposed to be restored as individual units, the patient goals, financial considerations, and plans may lead to preserving them as an interim solution.

Patient-level factors influence the overall prognosis and the likelihood of recovery from the disease, be it periodontal disease, caries, trauma, malocclusion, etc, resulting in alternative clinical decisions being reached that are more appropriate for the overall rehabilitation on the patient. The success of a particular treatment modality may also affect long-term prognosis of individual teeth, but since this is determined by the knowledge, skills, and comfort zone of the treating clinician, incorporating it into the classification would impair its main purpose—which is to focus on the patient's condition.

SUMMARY

Although the dental literature presents limited evidence-based data to support the use of specific criteria as prognostic tools, the profession has developed accepted guidelines for the evaluation of teeth. The authors developed the classsification system, based on evidence-based data whenever available and on a Delphi method process so as to accumulate the profession's accepted best practices.

Preliminary evaluation of this classification system has been well received upon expert peer-review analysis. In the last few years, dental students at Harvard School of Dental Medicine have been using this classification system as an educational tool. Although they had no previous experience in evaluating teeth, they were able to attach realistic prognostic values to teeth more accurately and more promptly than their predecessors, who did not use this classification system. Furthermore, students were able to devise better and more appropriate treatment plan options for their patients.

This article presents a classification system that aims to create a meaningful and standardized tool for use among dental professionals. The authors are aware of the complexities and the limitations of any tool that aims to attach prognostic values to teeth. However, modern dentistry would benefit from having a classification system that is comprehensive and standardized.

ACKNOWLEDGMENTS

The authors wish to acknowledge the following specialists and faculty for their input (by alphabetic order): Dr John Da Silva, Harvard University; Dr Renee Duff, University of Michigan; Dr Jacqueline Duncan, University of Connecticut; Dr Bernard Friedland, Harvard University; Dr German Gallucci, Harvard University; Dr Hamasat Gedaf-Dam, Geneva, Switzerland; Dr Foroud Hakim, University of the Pacific; Dr Nadeem Karimbux, Harvard University; Dr David Kim, Harvard University; Dr Natalie Leow, Sydney, Australia; Dr Jarshen Lin, Harvard University; Dr Zeev Ormianer, Ramat Gan, Israel; Dr Sharon Siegel, Nova University; Dr Noah Stern, Hebrew University, Israel; Dr Hans-Peter Weber, Harvard University; Dr Robert White, Harvard University; and Dr Robert Wright, Harvard University.

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