Tooth Morphology as a Local Modifier of Periodontal Disease and Treatment Response – A Critical Narrative Review.

Abstract:

Periodontal destruction varies between sites within the same dentition. Developmental grooves, ectopic enamel, root concavities, and furcation architecture may help explain this variation by influencing biofilm retention, tissue attachment, and access for treatment. However, their clinical importance is often overstated when anatomical observations are interpreted as proof of disease causation or inevitable treatment failure.This review critically examines how tooth morphology modifies local periodontal conditions and integrates anatomical assessment into diagnosis, treatment selection, and supportive care.This narrative review appraises landmark anatomical studies, clinical investigations, periodontal classification documents, and treatment guidance. The most defensible distinction is between anatomy that can facilitate plaque persistence, anatomy that complicates instrumentation, and anatomy that limits reconstructive or restorative options. These categories overlap but do not carry equivalent prognostic evidence. Furcation entrance dimensions can mismatch some conventional instruments, but this does not establish universal failure of nonsurgical therapy. Palatogingival grooves require differential diagnosis because associated lesions may involve periodontal and pulpal disease. Restorative contours and margins can compound local anatomical difficulties. Clinical examination and conventional radiography remain central. Three-dimensional imaging addresses a specific unresolved question likely to change management.Tooth morphology is a clinically relevant local modifier rather than a deterministic predictor of tooth loss. Treatment should integrate anatomical complexity with inflammation, remaining support, pulpal and restorative status, response to initial therapy, and maintenance feasibility. Prospective studies are needed to determine whether standardized morphological measurements improve outcome prediction beyond conventional periodontal findings.

Keywords: tooth morphology; periodontitis; furcation involvement; palatogingival groove; cervical enamel projection; supportive periodontal care

1. Introduction

A deep periodontal pocket confined to one tooth surface raises a practical question: why has destruction developed at this site while adjacent surfaces remain relatively stable? A whole-mouth diagnosis describes the patient's disease burden, but it does not fully explain local differences in access, plaque retention, or treatment response. Tooth-related developmental and acquired conditions therefore deserve attention alongside the broader clinical assessment. The 2017 World Workshop recognized these conditions within the classification of periodontal diseases and conditions [1].

Morphological findings should nevertheless be interpreted in context. An enamel projection or root concavity can exist without clinically important inflammation, while severe destruction can occur around teeth without conspicuous anomalies. The presence of an anatomical feature, its association with a lesion, and its independent ability to predict future breakdown are different propositions. Conflating them encourages overtreatment of stable teeth and premature pessimism about teeth that remain maintainable.

The staging and grading framework incorporates disease severity, management complexity, and evidence or modifiers of progression [2]. Detailed anatomical recording can supplement this framework, particularly when local findings are disproportionate to the rest of the dentition. It should not substitute for the formal diagnosis or be used to assign a new grade solely because a root is difficult to instrument.

This review develops the anatomy–periodontal interface into a clinical argument: morphology becomes actionable when it explains a diagnostic uncertainty, identifies an obstacle to effective treatment, or changes the feasibility of long-term maintenance. The review addresses ectopic enamel, developmental grooves, root and furcation architecture, restorative interactions, and emerging digital approaches. Its proposed assessment framework is intended to organize clinical reasoning and has not been validated as a prognostic score.

2. Review approach and boundaries

The supplied chapter on tooth morphology and periodontal pathology provided the thematic starting point. We conducted targeted web searches and consulted accessible journal pages and bibliographic records on 18 September 2026. Search concepts included cervical enamel projections, enamel pearls, palatogingival grooves, furcation entrance architecture, restorative overhangs, three-dimensional furcation assessment and periodontal treatment guidance.

Source selection was purposive and question-driven. Anatomical investigations were used to describe structure, clinical studies to examine associations or treatment observations, and consensus documents and guidelines to contextualize practice. No comprehensive database search, duplicate independent screening, formal risk-of-bias assessment, or meta-analysis was performed. Accordingly, no claim of exhaustive coverage, PRISMA compliance, or formally graded certainty is made. Where only bibliographic or abstract-level information was accessible, detailed numerical or procedural claims beyond that information were avoided.

The synthesis distinguishes direct observations from clinical interpretation. A measured narrow entrance supports concern about instrument access; it does not quantify the probability of tooth loss. Similarly, an association between a groove and bone loss does not establish how much of that association is independent of plaque control, previous treatment or selection into an imaging cohort. These distinctions guide the discussion and the research proposals below.

3. Developmental morphology at the periodontal interface

3.1. Cervical enamel projections

Cervical enamel projections extend apically from the cervical enamel outline toward or into a molar furcation. Masters and Hoskins' classic descriptiondistinguishes progressively greater extension toward the interradicular region [3]. Their relevance lies in location: a feature that reaches the furcation may alter the surface encountered by the soft tissues and restrict effective management once attachment loss exposes that area.

Enamel does not provide the same substrate for connective tissue fiber insertion as cementum. This difference should not be translated into the assertion that an epithelial attachment is intrinsically defective or destined to fail. Epithelial attachment is a normal component of the dentogingival interface. For a particular tooth, the clinically relevant questions are whether inflammation persists around the projection, whether the feature contributes to an inaccessible contour, and whether modifying it would improve access without unnecessary tissue damage.

A projection alone is therefore insufficient justification for prophylactic odontoplasty. For a stable, cleansable site, documentation and monitoring may be appropriate. When surgery is otherwise indicated, direct inspection can clarify the projection’s extent and its relationship to the defect. Assess any proposed removal against the amount of sound tissue sacrificed and the likely improvement in maintenance.

3.2. Enamel pearls

Enamel pearls are discrete ectopic enamel formations on root surfaces, often encountered around molars. Radiographic observations demonstrate that they occur in clinical populations, although measured prevalence depends on the imaging method and sample [4]. Their periodontal relevance depends on their size, position, relationship to the gingival margin, and accessibility after attachment loss. A small incidental pearl on an otherwise healthy tooth has a different clinical meaning from a nodule within an inflamed, inaccessible furcation.

Managing an enamel pearl requires assessing the adjacent root and the amount of tissue to be removed. Conservative evaluation should precede any attempt at recontouring. The objective is to resolve an identified local problem while preserving tooth integrity, rather than to make every root surface geometrically uniform.

3.3.Palatogingival grooves

Palatogingival or palatoradicular grooves are developmental depressions that may extend from the palatal crown onto the root, particularly in maxillary incisors. Kogon’s anatomical work described variation in their location and configuration [5]. The label therefore covers a spectrum: a short coronal groove and a deep groove extending apically should not be treated as interchangeable exposures.

A 2025 retrospective cone beam computed tomography (CBCT) investigation evaluated 3772 maxillary incisors from 943 patients and identified grooves in 107 teeth, corresponding to 2.8% at tooth level. Grooves were associated with periodontal bone loss and periapical lesions [6]. These findings support targeted clinical examination but do not establish prospective risk. Imaging referral, the definition of a visible groove, and lack

of temporal sequencing limit interpretation. Tooth-level prevalence must also be distinguished from the proportion of patients with at least one affected tooth.

Clinically, an isolated narrow pocket on the palatal aspect of an incisor should prompt inspection for a groove, pulpal testing and assessment for competing explanations. A fracture, endodontic drainage pathway, perforation or localized periodontal lesion can produce partially overlapping findings. Pulpal disease should be diagnosed, not presumed from pocket depth alone. The extent of a groove, remaining root structure and possibility of producing a sealed, maintainable surface influence whether conservative management is feasible.

4. Root architecture and access to treatment

4.1. Root concavities

Root concavities are ordinary anatomical variations rather than disease entities. Their importance changes when attachment loss exposes them to the pocket environment. A depression that was previously incorporated within the supporting apparatus may become difficult to clean, particularly if its entrance lies beneath a restoration or a narrow interdental space. Bower's anatomical investigation of furcation root surfaces illustrates the complexity that can be concealed behind an apparently simple entrance [7].

The relevant mechanical problem is surface adaptation. An instrument may pass into a pocket while failing to contact part of a concavity. Access and contact are therefore separate properties. Instrument angulation, working-end dimensions, and the route of approach should be considered before persistent inflammation is attributed to a biologically refractory lesion. Conversely, repeated instrumentation without reassessing the surface can remove sound root tissue without correcting the inaccessible area.

4.2. Furcation entrance dimensions

Bower examined 114 maxillary and 103 mandibular first molars and reported that 58% of the furcation entrances studied were narrower than the blade-face width of commonly used curettes [8]. This remains a useful demonstration of instrument–anatomy mismatch. It is not a clinical failure rate: extracted-tooth measurements neither reproduce contemporary instrumentation nor measure healing, disease recurrence, or tooth retention.

The appropriate inference is that curettes used alone may have incomplete access in some furcations. Treatment planning should consider different working ends, powered instrumentation where appropriate, operator access, and the possibility of direct visualization. A narrow entrance increases technical difficulty. Clinicians must still observe the clinical response. The frequently repeated claim that such anatomy guarantees failure of nonsurgical therapy is unsupported by the measurement itself.

4.3. Root trunk length and root separation

Root trunk length determines how far attachment loss must extend apically before reaching the furcation. A short trunk may expose an interradicular region relatively early, whereas a long trunk can delay that exposure. Once involvement develops, however, the amount and distribution of remaining support become more informative than trunk length alone. Root divergence, fusion, curvature and the vertical component of the defect also affect access and possible treatment routes.

Neither a long trunk nor advanced furcation involvement should automatically be equated with a hopeless prognosis. Likewise, widely separated roots do not guarantee a favorable result. Prognosis requires an integrated judgment about support, mobility, restorability, endodontic status, treatment burden, and the patient's ability to maintain the tooth. Record these variables explicitly when they drive a retention or extraction decision.

4.4. Root proximity

Closely approximated roots can complicate interdental access and restorative or surgical procedures. However, a narrow interradicular space should not be described as an independent cause of rapid bone loss without appropriate longitudinal evidence. It may coexist with crowding, difficult hygiene, and unfavorable restorative contours. A useful clinical record distinguishes the observed proximity from the demonstrated consequences, such as inability to pass a suitable cleaning aid or restricted access to a residual lesion (Figure 1).

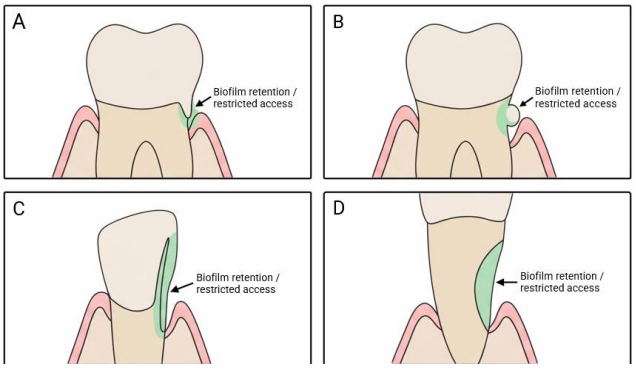

Figure 1.Tooth morphology as a local modifier of periodontal vulnerability. Schematic illustrations of (A) a cervical enamel projection extending toward the molar furcation, (B) an enamel pearl on the root surface, (C) a palatogingival groove extending from the palatal crown onto the root, and (D) a root concavity. Highlighted areas indicate potential sites of biofilm retention or restricted access for oral hygiene and professional instrumentation in the periodontal pocket environment. These anatomical features may complicate local disease management but do not independently establish disease activity or determine tooth prognosis. Illustrations are schematic and not to scale.Created in BioRender. Beresescu, F. G. (2026) https://BioRender.com/moo2v3e

Table 1 summarizes anatomical evidence and the clinical interpretation developed in this review [3–8].

Table 1Anatomical findings and the questions they should trigger

Finding	Main clinical question	Interpretive limit
Cervical enamel projection	Does the extension contribute to an inflamed or inaccessible furcation?	Its presence alone does not mandate removal.
Enamel pearl	Is the nodule relevant to the lesion and can it be managed conservatively?	External appearance does not establish internal composition.
Palatogingival groove	How extensive is the groove and is there pulpal involvement?	An isolated pocket is not specific for a groove.
Root concavity	Can the working end contact the affected surface?	Instrument entry does not ensure surface contact.
Complex furcation	What are the horizontal and vertical defects and remaining support?	Entrance width is not a clinical failure probability.
Root proximity	Does the space prevent cleaning or constrain treatment?	Proximity alone does not establish future breakdown.

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5. Restorative contours and supracrestal tissues

Restorations create an additional interface between tooth morphology and the periodontium. Historical histological measurements by Gargiulo and colleagues established the importance of the dimensions of the dentogingival junction [9]. An average dimension should not be applied as a fixed biological constant to every tooth. Tissue dimensions and the clinical position of a restorative margin require site-specific assessment.

Experimental clinical work by Lang and colleagues linked overhanging subgingival margins to adverse local microbiological and inflammatory changes [10]. This provides a stronger basis for correcting an accessible plaque-retentive overhang than for removing an asymptomatic developmental feature merely because it is unusual. Nevertheless, correction should address the actual contour and the patient's ability to clean it; replacing a restoration without improving its emergence profile may reproduce the same problem.

The tooth-related and prosthetic factors considered in the World Workshop include relationships among

restorative margins, tissue attachment, and periodontal inflammation [11]. Their clinical implications are particularly relevant where a restoration meets a root concavity. The objective is a smooth, appropriately contoured, and maintainable transition. Literal reproduction of every anatomical depression is not necessarily required, and a convex appearance alone does not prove tissue damage.

Evaluate a proposed deeper margin in relation to caries extent, isolation, tissue dimensions, restorative material, and access for maintenance. Surgical crown lengthening and orthodontic extrusion may be options in selected cases, but neither should be described as obligatory whenever anatomy is difficult. The loss of supporting tissue, esthetic consequences, treatment time, and final restorative prognosis should be considered in the same decision. This is especially important for molars when apical displacement of the margin could expose or approach a furcation.

6. Diagnosis and selective imaging

Clinical assessment should connect the suspected feature with a reproducible lesion pattern. Six-site probing, recession measurements, clinical attachment level, bleeding or suppuration, mobility and furcation examination establish the baseline. Local inspection and appropriate tactile exploration can then address developmental grooves or restorative discrepancies. The chart should identify the specific tooth surface and the diagnostic uncertainty rather than record only a general label such as complex anatomy.

Conventional intraoral radiographs provide information about support, roots, restorations, and periapical tissues. Superimposition can obscure maxillary furcations and certain root configurations. Walter and colleagues investigated three-dimensional imaging for maxillary molar furcation assessment [12]. This supports considering CBCT in selected diagnostic problems, while not establishing that routine scanning improves outcomes for all patients with periodontitis.

Before requesting CBCT, the clinician should specify what decision depends on the result. Examples include uncertainty about a complex furcation before surgery or an unusual root configuration affecting a feasible retention strategy. The field of view and exposure should be appropriate to that question. Artifacts, spatial resolution and the distinction between mineralized structures and soft tissue attachment remain relevant. A more detailed image does not, by itself, demonstrate current inflammatory activity or prove that a small enamel anomaly is clinically important.

Optical intraoral scanning has a different role. It documents accessible surfaces and can support serial comparison of visible soft tissues or restorative contours. It does not directly reveal root morphology beneath intact tissues. Combining optical scans with radiographic information can aid planning, but the accuracy and limitations of each modality should remain explicit.

7. Treatment selection and reassessment

The EFP S3 guideline for stage I–III periodontitis supports incremental care incorporating risk-factor and biofilm control, subgingival instrumentation, further treatment of residual disease and supportive periodontal care [13]. Complex morphology fits within this sequence. It may influence how an intervention is delivered and how soon a site requires reassessment, without automatically bypassing initial therapy.

Reassessment should establish whether an anatomical concern remains clinically consequential. Persistence of a deep inflamed pocket after adequate initial care is a different situation from a stable residual contour without bleeding or progression. Before escalation, clinicians should reconsider plaque access, instrumentation, restorative defects and diagnostic alternatives. Repeated nonsurgical treatment is not categorically contraindicated, but repetition without an identifiable purpose or evidence of benefit is difficult to justify.

7.1. Access and conservative surface modification

Access surgery may allow direct inspection and treatment of a surface that cannot be managed adequately through a closed approach. The decision should follow the residual lesion and its treatment options rather than the presence of an anatomical label alone. During surgery, the extent of any odontoplasty should be limited to the problem being addressed. Removing ectopic enamel does not guarantee new connective tissue attachment, and excessive root reduction may trade one difficulty for structural weakness or hypersensitivity.

For developmental grooves, the management plan may combine periodontal access, conservative recontouring and sealing of a suitable defect. Endodontic treatment is relevant when pulpal diagnosis warrants it. These choices are highly dependent on root thickness, groove depth and the possibility of a durable interface. They should not be presented as a standardized combination for every affected incisor.

7.2. Regenerative and resective approaches

A systematic review and network meta-analysis of randomized trials supports regenerative treatment for

selected furcation defects, with much of the evidence concerning class II lesions [14]. This evidence should not be generalized to all furcation locations or through-and-through defects. Defect configuration, access, wound stability and patient factors influence applicability. Clinical attachment gain or radiographic fill must also be distinguished from histological demonstration of regeneration.

Resective approaches, including root resection or separation, can be considered for selected teeth when the retained component has adequate support and a feasible restorative plan. The systematic review by Dommisch and colleagues describes a heterogeneous evidence base rather than a universally superior solution [15]. Endodontic feasibility, fracture risk, root caries, strategic value and long-term cleaning access should be incorporated before treatment begins. Resection converts anatomy but does not remove the need for maintenance.

7.3. Supportive care

Anatomically difficult sites require a maintenance plan that can be implemented outside the surgery. The clinician should demonstrate the appropriate cleaning route and verify that the patient can reproduce it. Documentation of access from the buccal or lingual aspect is more useful than a generic instruction to improve oral hygiene. A technically successful intervention has limited value if the resulting contour remains inaccessible.

Long-term observational work relates residual probing depths and recall timing to periodontal stability during supportive therapy [16]. For a morphologically complex tooth, monitoring should therefore retain site-level findings rather than depend solely on whole-mouth averages. Recall timing should reflect the overall periodontal risk and response, with attention to the affected site. This review does not propose an anatomy-only recall interval (Figure 2).

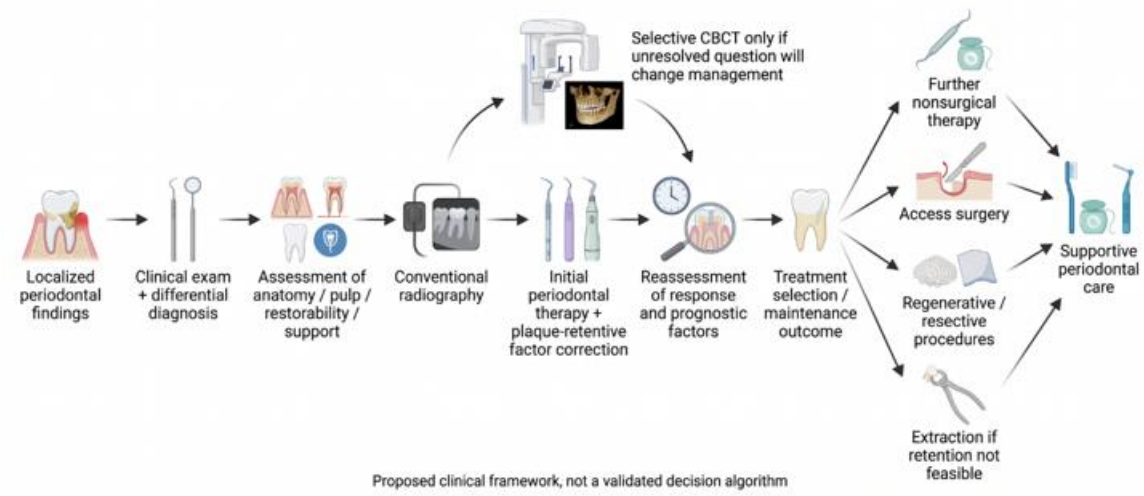

Figure 2. Proposed clinical pathway for periodontal sites with complex tooth morphology. Localized periodontal findings prompt clinical examination, differential diagnosis, and assessment of anatomical features, pulpal status, restorability, and remaining periodontal support. Conventional radiography is supplemented by cone beam computed tomography only when a specific unresolved diagnostic question is likely to influence management. Initial periodontal therapy and correction of relevant plaque-retentive factors are followed by reassessment. Subsequent care is selected according to residual inflammation, access, defect configuration, treatment response, and maintenance feasibility. Options include further nonsurgical treatment, access surgery, selected regenerative or resective procedures, or extraction when retention is not feasible. Retained teeth enter individualized supportive periodontal care. This pathway is a proposed clinical framework, not a validated decision algorithm. Created in BioRender. Beresescu, F. G. (2026) https://BioRender.com/moo2v3e

Table 2 is an author-proposed documentation framework, informed by classification and treatment principles [1,2,13–16].

Table 2.Proposed framework for documenting a morphologically complex periodontal site

Domain	Record	Decision supported

Domain	Record	Decision supported
Disease status	Probing depth, attachment level, bleeding, suppuration and change over time	Whether the site needs active treatment or observation
Anatomy	Feature, location, extent and confidence of identification	Which obstacle or uncertainty is relevant
Access	Patient cleaning route and professional surface contact	Whether access can be improved conservatively
Tooth integrity	Restorability, pulpal status, remaining structure and support	Whether retention strategies are feasible
Treatment response	Findings after initial care and correction of local defects	Whether further intervention has a defined purpose
Maintenance feasibility	Demonstrated home care, attendance and patient preferences	Whether the proposed outcome is sustainable

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8. Evidence gaps and research priorities

The evidence is uneven across the anatomy–treatment pathway. Extracted-tooth studies can measure fine structural features but usually cannot establish the preceding disease history. Cross-sectional clinical and imaging studies can identify associations but may preferentially include symptomatic or complex cases. Case reports can demonstrate technical feasibility without estimating comparative effectiveness. Treatment trials may classify furcation involvement while incompletely describing the root features that could modify their results.

A prospective study should distinguish baseline morphology from changes resulting from disease or treatment. Enrollment should occur before the outcome being predicted, and anatomical measurements should be reproducible between examiners. Sites are nested within teeth and patients, so statistical analysis must account for clustering. Baseline attachment loss, smoking, glycemic status, plaque control, tooth type and maintenance exposure are potential confounders or competing predictors that require consideration.

A useful endpoint would be sustained pocket closure or recurrent attachment loss, complemented by patient-centered outcomes and tooth retention over an appropriate duration. Demonstrating a statistically significant association with a morphological feature is insufficient to justify a prediction tool. Investigators should test whether adding the feature improves calibration, discrimination and clinically useful decisions beyond a model based on conventional findings. External validation should precede routine use.

Digital segmentation and artificial intelligence could reduce the burden of measuring root configurations, but a visible structure is not automatically a clinically actionable target. Studies should address reproducibility, artifacts, error across scanners and whether automated findings actually change appropriate decisions. Patient-specific regenerative scaffolds are another research direction. Their geometric fit, biological performance and long-term clinical value require separate evaluation; customization alone does not demonstrate regeneration or improved tooth survival.

Table 3. Research questions and suitable study designs

Question	Design	Essential safeguard
Does morphology predict recurrence?	Prospective multilevel cohort with standardized supportive care	Adjust for baseline disease and patient-level risks
Does access adaptation improve outcomes?	Pragmatic comparative trial at defined anatomical sites	Record treatment delivery and patient cleaning ability

Question	Design	Essential safeguard
When does CBCT change appropriate management?	Prospective diagnostic and decision-impact study	Compare with conventional assessment and record radiation exposure
Can automated measurements be trusted?	Multicenter accuracy and reproducibility study	External testing across devices and artifact conditions
Do customized regenerative constructs add benefit?	Staged safety and controlled clinical evaluation	Separate geometric fit from biological and clinical outcomes

9. Limitations

This review is a targeted narrative synthesis rather than an exhaustive evidence inventory. Source selection may favor established anatomical descriptions and accessible publications, and formal certainty ratings were not generated. Findings from historical instrumentation studies may not transfer directly to current devices or operator techniques. Evidence concerning individual rare anomalies is less extensive than evidence addressing periodontitis treatment generally. The assessment framework and research priorities represent the interpretation developed here and should be tested before they are used as formal decision rules.

10. Conclusions

Tooth morphology can influence where plaque persists, which surfaces can be instrumented and what treatment outcomes are maintainable. Its clinical meaning depends on the lesion and the patient. Developmental anomalies should prompt careful diagnosis; furcation architecture should inform access and feasibility; restorative contours should permit cleaning and respect the periodontal interface. Escalation of care should follow residual disease and a defined treatment objective. The next research priority is to determine which anatomical measurements add useful prognostic information beyond conventional periodontal assessment.

Ethics approval and informed consent: Not applicable to this narrative review. No participants were enrolled and no individual patient data are reported.
Data availability: No new dataset was generated or analyzed.
Conflict of interest statement:The author declare no conflict of interest.

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