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INTEGRATED CLINICAL AND FUNCTIONAL ASSESSMENT OF DENTAL HARD-TISSUE DISORDERS: A RISK-ADAPTED FRAMEWORK FOR TREATMENT OPTIMIZATION

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ABSTRACT

Background: Dental caries, erosive tooth wear, abrasion and attrition may share the clinical endpoint of irreversible hard-tissue loss, yet their etiologic mechanisms and management requirements differ. Structural assessment alone may overlook pain, altered mastication and functional consequences. Objective: To synthesize evidence concerning the clinical and functional evaluation of dental hard-tissue disorders and propose a risk-adapted decision framework linking diagnosis with minimally invasive and rehabilitative care. Materials and Methods: A targeted narrative synthesis was developed from an Uzbek-language chapter organized around etiology, clinical diagnosis, functional assessment and treatment optimization. The chapter was critically reorganized and contextualized using 18 independently identifiable guidelines, consensus papers and peer-reviewed reviews. No patient dataset was available or analyzed. Results: The synthesis supports structured visual-tactile lesion assessment as the first-line diagnostic step; bitewing radiography and optical methods are adjuncts used when clinically indicated. Erosive wear and tooth-wear scoring systems provide a separate phenotype-specific pathway. Functional testing—including mastication, jaw symptoms and occlusal-contact analysis—adds relevant information in selected symptomatic patients but does not establish the cause of lesions in isolation. Four evidence-to-practice tables and a staged clinical decision pathway integrate lesion activity, caries risk, functional impact and patient preferences. Conclusions: A combined lesion-centered and patient-centered assessment can support proportionate treatment, facilitate non-operative disease control where appropriate and reserve complex restorative or functional interventions for justified indications. Prospective validation of the proposed framework is required.

Keywords: dental hard tissues; dental caries; erosive tooth wear; clinical diagnosis; functional assessment; bitewing radiography; digital occlusal analysis; minimally invasive dentistry; personalized treatment.

INTRODUCTION

Oral diseases remain a substantial international public-health concern. The World Health Organization estimates that oral conditions affect nearly 3.7 billion people worldwide, while untreated caries in permanent teeth remains the most prevalent condition in the

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Global Burden of Disease 2021 estimates [1]. Dental caries is neither a purely infectious defect nor an inevitable consequence of aging; it is a biofilm-mediated, sugar-driven, dynamic process resulting from repeated shifts between demineralization and remineralization [2]. Other hard-tissue disorders, including erosive tooth wear, attrition and abrasion, can reduce tooth structure through chemical or mechanical processes and may coexist with caries. Their overlapping clinical appearance creates diagnostic ambiguity when treatment planning relies only on the visible extent of tissue loss.

Effective care consequently requires two complementary viewpoints. The first is disease oriented: the practitioner identifies lesion type, location, severity, activity and etiologic exposures. The second is patient oriented: symptoms, chewing ability, esthetic concerns, functional loading, financial constraints and willingness to undertake preventive measures influence the benefit and burden of an intervention. The International Caries Classification and Management System (ICCMS) explicitly connects lesion diagnosis with risk-based care planning [3], and recent ORCA–EFCD consensus recommendations place structured visual assessment, lesion activity and individual-level etiologic assessment at the center of clinical decisions [4–6]. These principles suggest that additional technologies should be selected according to an unresolved clinical question rather than used universally.

The present paper develops an integrated conceptual approach to the diagnosis and treatment of dental hard-tissue disease from the four themes of the supplied academic chapter: epidemiology and pathogenesis; clinical lesion assessment; functional evaluation of the dento-masticatory system; and optimization of prevention and restorative therapy. Its objective is to clarify the evidentiary status and limitations of individual diagnostic methods and to formulate a usable, but as yet unvalidated, risk-adapted framework. No effectiveness advantage for this newly proposed framework is claimed without empirical testing.

LITERATURE REVIEW

The biological foundation of contemporary caries care rests on the ecological and behavioral nature of the disease. Frequent fermentable-carbohydrate exposure promotes acidogenic activity within the dental biofilm, whereas saliva, fluoride exposure and protective behaviors may help maintain conditions favorable to remineralization [2]. The ICCMS pathway therefore separates the observation of a lesion from a comprehensive caries-risk appraisal and subsequent decisions about preventive, non-operative or operative management [3]. Recent individual-level diagnostic recommendations likewise emphasize that risk factors and modifying circumstances must accompany lesion findings before personalized treatment can be selected [6]. For erosive wear and mechanically driven tissue loss, acidic exposure, parafunctional activity, tooth-contact patterns and functional complaints require a partly different diagnostic history and risk-control strategy.

The methodological literature supports a carefully staged examination. A Cochrane review demonstrates that visual or visual-tactile approaches are essential in early caries detection, although estimates vary across settings and reference standards [7]. Another Cochrane review addresses the accuracy and limitations of imaging-based methods [8]. Optical

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transillumination and optical coherence tomography offer potentially useful non-ionizing alternatives in selected contexts, but evidence does not establish their superiority in every setting [9]. The ORCA–EFCD 2024 expert panel recommends a structured visual-tactile assessment as the first choice on accessible surfaces and bitewing radiography as an additional method according to indication, while specifically discouraging routine CBCT solely for caries detection [4]. Lesion activity remains a composite clinical judgment rather than the product of one isolated test or color feature [5].

Tooth-wear diagnostics involve distinct measurement systems. The Basic Erosive Wear Examination (BEWE) offers a practical means to record erosive surface loss and guide risk-oriented follow-up [10]. The Tooth Wear Evaluation System 2.0 (TWES 2.0) provides a structured taxonomy of clinically relevant wear patterns, while subsequently proposed diagnostic criteria and reliability investigations emphasize the importance of reproducible terminology, calibration and clinical history [11,12,18]. These tools are complementary rather than interchangeable with caries grading, because they capture fundamentally different processes and clinical questions.

Functional assessment provides information beyond lesion depth. Evaluation of mastication, pain, mandibular movement and temporomandibular symptoms can reveal needs that are not captured by a chart of tooth surfaces. However, a 2025 systematic review concluded that digital occlusal methods are more reliable for depicting contact location than for accurately quantifying contact intensity or guiding occlusal corrections [14]. When a temporomandibular disorder is suspected, validated DC/TMD concepts, including the relationship between symptoms and standardized examination, are preferable to assuming that tooth wear or contact asymmetry establishes joint disease [15]. Thus, function should be assessed purposefully and interpreted without overattributing causation.

The treatment literature reinforces a conservation-oriented approach. An American Dental Association guideline recommends selected nonrestorative interventions, such as topical fluoride, sealants and silver diamine fluoride, for specified lesion and tooth contexts [16]. Its subsequent restorative guideline addresses carious-tissue removal and material selection for lesions requiring operative intervention [17]. Digital technologies and artificial intelligence may support recognition and documentation, but their implementation depends on representative validation, clinician oversight and an understanding of potential bias and generalizability problems [13]. Collectively, these sources identify an unmet implementation problem: clinicians need a transparent way to relate structural disease activity, functional consequences, risk exposures and treatment intensity without mistaking technological sophistication for clinical necessity.

MATERIALS AND METHODS

This study was structured as a source-based narrative clinical and methodological synthesis. The primary material was the uploaded Uzbek-language chapter entitled “Clinical-functional characteristics of dental hard-tissue diseases and theoretical foundations of treatment optimization,” organized into four thematic parts: epidemiology, etiology and pathogenesis; clinical assessment methods; functional assessment methods; and integrated

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treatment optimization. Its propositions were grouped into a conceptual evidence matrix. Relevant published guidance and indexed reviews were then consulted to refine terminology and assess whether the proposed clinical sequence was supported, debated or outside the direct scope of available evidence [1–18].

For the narrative evidence appraisal, materials were prioritized if they were international clinical guidelines, professional consensus documents, systematic reviews or well-characterized methodological papers directly relevant to one of four clinical questions: (1) what initiates and maintains lesion activity; (2) how should tissue loss be identified and staged; (3) what functional tests add patient-important information; and (4) when should disease control, non-operative care or restorative intervention be favored? Search concepts included dental caries detection, lesion activity, bitewing radiography, erosive tooth wear, BEWE, TWES 2.0, occlusal analysis, mastication, caries management, selective caries removal and AI in dental diagnosis. Eighteen traceable sources were retained for citation, including primary guideline or database records where available. The source chapter contains many numbered citations without its full corresponding reference list; those original numbers were not mechanically copied into the new article.

The synthesis deliberately avoided meta-analysis and retrospective numerical reconstruction. No patient-level observations, numerical effectiveness estimates, study-arm frequencies, sensitivity calculations or follow-up outcomes were supplied in the chapter. The results therefore describe a qualitative integration framework and selected published consensus percentages, not an experimental validation of the proposed pathway. Proposed steps were checked for consistency with published recommendations and explicitly separated from evidence that establishes intervention efficacy. Because no human participants were recruited or identifiable clinical records processed, ethics approval was not required for preparation of this literature-based manuscript. No systematic-review registration, independent dual screening or formal risk-of-bias scoring was undertaken; the review should not be described as a systematic review.

RESULTS

The synthesis identifies a practical distinction between four major hard-tissue phenotypes. Caries reflects a localized, biofilm-driven mineral imbalance; erosive wear is associated with non-bacterial acid exposure; abrasion involves frictional mechanical loss; and attrition reflects tooth-to-tooth contact. These categories can coexist within one dentition, making a one-lesion–one-cause assumption inappropriate. Functional symptoms—sensitivity, chewing difficulty, esthetic compromise or jaw pain—are not themselves etiologic diagnoses, but they determine the need for additional assessment and may change treatment priorities. Table 1 maps the relation between dominant exposures, clinical indicators and initial decisions.

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Table 1. Etiologic phenotype and its implications for assessment and initial care

Predominant phenotype	Clinical pattern / context	Key diagnostic question	Initial risk-focused response
Caries	Plaque-retentive surfaces; white/brown lesions or cavitation; repeated sugar exposure	Is the lesion active, cavitated and progressing?	Document activity and risk; prioritize plaque and diet control, fluoride, lesion-specific care [2–6].
Erosive tooth wear	Smooth or cupped loss; dietary or intrinsic acid history	Are acidic exposures ongoing, and what is the degree of wear?	Assess exposure and BEWE; preventive counseling and monitor progression [10].
Attrition / abrasion	Faceted contact wear or friction-related localized loss	Is there ongoing mechanical loading or harmful habit?	Examine pattern, exposure and symptoms; avoid causal inference from facets alone [11,12].
Mixed disease / symptomatic wear	Combination of tissue loss, restorations, hypersensitivity or chewing changes	Which component is active and which causes disability?	Multimodal assessment with staged, minimally invasive and functional planning [3,11,15].

The first diagnostic decision is the quality of the clinical examination. Cleaning and drying the surface, adequate illumination and structured lesion scoring support reliable visual assessment; the clinician should then determine activity and identify the patient's risk modifiers. In the ORCA–EFCD Paper I Delphi process, expert agreement was 100% for visual-tactile examination as the first-choice method, 100% for indicated intraoral radiography as an adjunct, and 90% for collecting lesion-activity information during visual assessment [4]. These are consensus agreement rates, not sensitivity, specificity or measured treatment success rates. Figure 1 displays those agreement values solely to illustrate the strength of panel endorsement.

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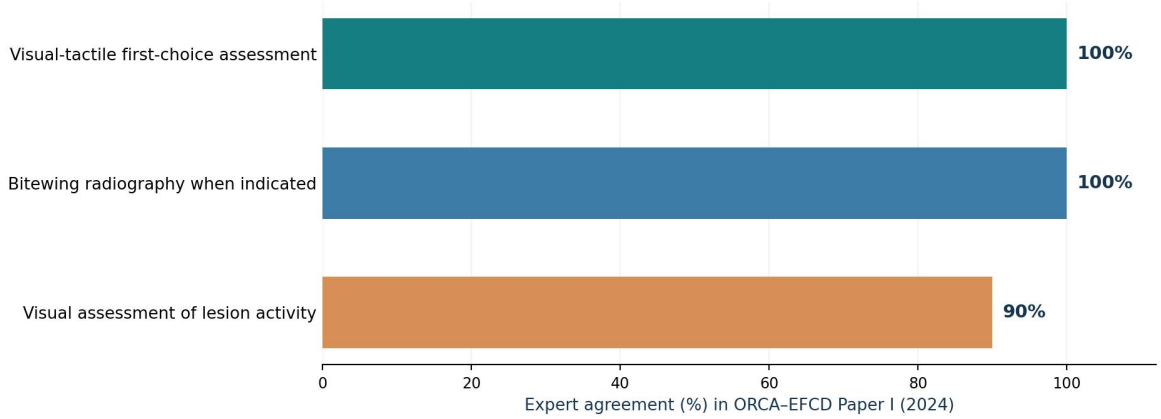


Figure 1. Selected ORCA–EFCD 2024 Paper I Delphi agreement rates for three diagnostic recommendations [4]. Percentages represent expert agreement, not test accuracy.

Table 2 summarizes diagnostic modalities through their intended contribution and constraints. Bitewing imaging is particularly useful when hidden proximal disease is suspected and a radiograph could alter management, but exposure must be individually justified. CBCT is not a routine caries test. Near-infrared transillumination and fluorescence can provide additional information where available, although their incremental clinical benefit depends on the lesion and reference standard. Digital technologies must therefore remain adjuncts to structured clinical reasoning rather than automatic substitutes [4,7–9,13].

Table 2. Diagnostic techniques for dental hard-tissue disease: indication and limitations

Modality	Principal purpose	Strength	Main limitation / safeguard
Visual-tactile examination	Stage lesion severity and infer activity	First-line and broadly accessible	Interobserver variation; requires cleaning, drying and calibration [4,5,7].
Bitewing radiography	Assess hidden proximal and dentinal lesions	Adds information unavailable on direct inspection	Ionizing radiation; early lesions can be underestimated; indication-based use [4,8].
NIR / FOTI / OCT or fluorescence	Clarify specific surfaces or monitor selected lesions	Potential radiation-free adjunct	Device-specific accuracy, access and false-positive/negative findings [9].
BEWE / TWES 2.0	Characterize erosive or mechanical wear	Standardized longitudinal descriptive record	Does not establish isolated etiology or automatically determine treatment [10–12,18].

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Modality	Principal purpose	Strength	Main limitation / safeguard
AI-assisted imaging	Second reader / measurement assistance	Promising consistency and triage support	Dataset shift, clinical generalizability, explainability and oversight [13].

The proposed integrated evaluation begins with a focused etiologic history, followed by a structured description of tissue loss and lesion activity. Functional evaluation is then triggered by a patient-important symptom or a planned reconstruction for which an assessment may change care. Figure 2 summarizes how biological, chemical, mechanical and contextual processes contribute to a structural phenotype and to patient-level functional impact. The graphic is a conceptual causal map, not an epidemiologic model or a claim that occlusal findings alone predict disease.

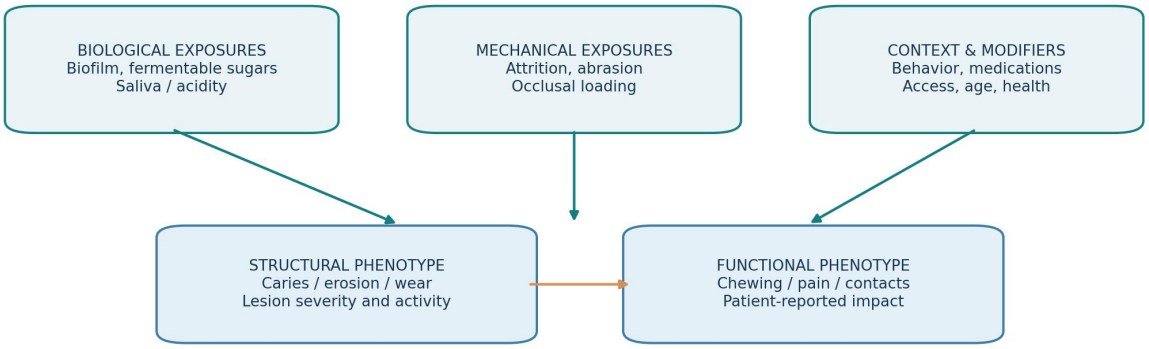


Figure 2. Conceptual integration of etiologic exposures, structural findings and functional consequences; proposed synthesis, not a validated causal model.

Functional tests have a supportive rather than universal role. Chewing history and a simple description of dietary adaptations may document the patient's burden; palpation, range of motion and relevant DC/TMD assessment become appropriate when jaw symptoms are present. Occlusal markings or sensors may inform description of contacts during complex restorative planning, but current evidence does not justify using contact-intensity displays alone to diagnose temporomandibular disorders or prescribe irreversible occlusal correction [14,15]. Table 3 distinguishes routinely useful patient-reported data from advanced measures whose utility depends on a defined indication.

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Table 3. Function-oriented measurements and interpretation safeguards

Domain	Suggested measure	Potential decision informed	Interpretation caveat
Patient experience	Pain/sensitivity, difficulty chewing, preferred foods, quality-of-life complaint	Urgency and patient-important therapeutic goals	Symptoms may be unrelated to lesion depth; ask about alternatives.
Clinical jaw function	Mouth opening, joint and muscle symptoms, standardized examination if TMD suspected	Referral or additional diagnostic assessment	Use DC/TMD when appropriate; no automatic link from wear to TMD [15].
Occlusal contacts	Articulating film or indicated digital contact mapping	Documentation during complex rehabilitation	Contact presence more defensible than absolute force quantification [14].
Chewing performance	Standardized chewing task or validated measure where available	Functional baseline / rehabilitation monitoring	Depends on testing protocol; not indicated for every early caries lesion.
Surface change over time	Standardized photographs, wear scores, repeated lesion activity assessment	Decide whether preventive care is stabilizing the condition	Photographic consistency and examiner calibration are essential [5,10–12].

The evidence-to-decision synthesis favors a prevention-first strategy for active but noncavitated caries, with treatment chosen according to lesion location, activity and feasibility. Once operative treatment is required, selective tissue removal and material choice should follow lesion depth, pulp health and current restorative guidance rather than a uniform aggressive excavation rule [16,17]. Erosive wear and abrasion require elimination or mitigation of ongoing exposures, surveillance of the degree of tissue loss and restorative management only when loss is progressive, symptomatic or functionally significant. For extensive rehabilitation, muscle or jaw symptoms and the feasibility of a stable restorative design must be considered before irreversible procedures [10–12,15].

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Table 4. Risk-adapted management matrix derived from the reviewed literature

Clinical situation	Preferred management focus	Indicators for escalation / reassessment	Evidence basis
Noncavitated active caries	Behavioral support, fluoride-based nonrestorative care, surface-specific preventive measures	Continued activity, progression, new cavitation, high-risk history	ICCMS; ORCA–EFCD; ADA [3,5,6,16]
Cavitated caries needing restoration	Disease control plus conservative restoration and evidence-based removal strategy	Pulpal signs, inadequate cleansability, structural compromise	ADA restorative guideline [17]
Initial erosive wear	Acid-exposure assessment, tailored prevention and serial BEWE documentation	Progression, hypersensitivity, loss of function	BEWE and TWES literature [10–12]
Mixed advanced wear / functional disability	Prioritize cause control and individualized staged rehabilitation	Persistent pain, chewing impairment, complexity requiring referral	TWES and functional standards [11,12,15]
Uncertain or discordant test findings	Re-examination, documentation, second opinion or validated adjunct	Result would materially change intervention choice	ORCA–EFCD and imaging reviews [4,7–9,13]

The operational result is a five-step clinical workflow (Figure 3). After initial phenotyping and risk assessment, the clinician selects only the tests needed to resolve uncertainty; combines lesion-level findings with symptomatic functional status; makes an explicit choice among preventive, nonrestorative and restorative strategies; and establishes follow-up using lesion activity, patient goals and treatment burden. The sequence is iterative because new symptoms or progression can justify reconsidering the initial diagnosis. Neither the five stages nor the tables constitute a validated clinical prediction model, and prospective measurement of adherence, inter-rater reproducibility and patient-reported outcomes will be required to assess their value.

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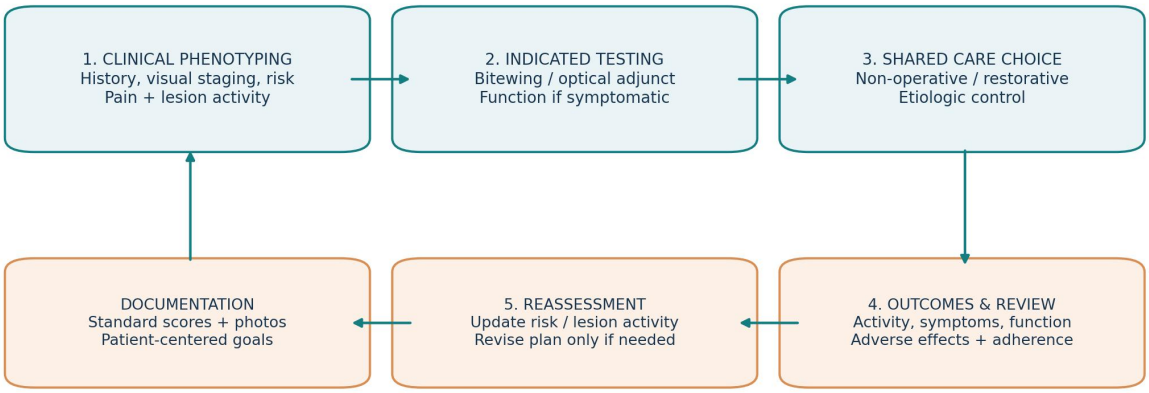


Figure 3. Proposed risk-adapted decision pathway linking phenotyping, selected adjunct tests, proportional treatment and reassessment.

DISCUSSION

The main contribution of this review is conceptual integration rather than a new estimate of disease prevalence or diagnostic accuracy. The source chapter treats lesions, occlusal function and rehabilitation as interrelated dimensions of dental care. Published guidance helps refine that broad framework into a practicable sequence that begins with reliable lesion detection and assessment of activity, followed by selected functional tests and proportionate therapy. This ordering is consistent with the clinical priority given to structured visual examination and individualized risk factors in ORCA–EFCD consensus documents [4–6]. It also guards against technology-driven intervention, where extensive testing occurs despite an absence of clinical uncertainty or an actionable result.

A key point is that dental hard-tissue loss does not have one mechanism. Carious lesions involve a biofilm ecology and mineral imbalance, whereas erosive lesions are primarily linked to chemical exposure and attrition to tooth contact. When multiple mechanisms coexist, treating a visible defect without modifying the causative exposure may yield recurrent or progressive problems. An integrated history also makes room for restorative margins, dietary frequency, saliva-related factors, toothbrushing habits, medication-related dryness and patient preference. The need to distinguish disease detection from activity and individual risk is supported by the ICCMS pathway and the three linked 2024 consensus documents [3–6].

The functional component warrants particular caution. It is tempting to regard an asymmetrical occlusal sensor display, high masseter electromyographic reading or broad wear facet as proof of dysfunction. Yet current systematic evidence does not provide adequate support for isolated numerical contact-intensity measurements as a basis for occlusal diagnosis or correction [14]. The proposed framework consequently restricts

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enhanced functional testing to cases where the result may change rehabilitation, symptom management or referral. For individuals with suspected temporomandibular disorder, standardized diagnostic criteria are more appropriate than causal claims based on a single contact pattern [15]. This principle protects patients from unnecessary, irreversible adjustments.

Conservative treatment similarly requires nuanced decision-making. Nonrestorative strategies are evidence-supported for particular caries states but cannot replace operative intervention when extensive cavitation, restoration failure or structural compromise necessitates repair. Conversely, a radiographic or optical observation alone should not trigger drilling when the lesion is inactive, cleansable and manageable by evidence-based preventive options. The ADA guidelines separate nonrestorative and restorative decision points and support a lesion-specific rather than one-size-fits-all approach [16,17]. Wear-related rehabilitation likewise depends on the severity, progression, symptoms and patient expectations; it is not automatically warranted whenever a numeric wear index is elevated.

Several limitations restrict inference. The uploaded chapter is an extensive background synthesis rather than a report of clinical patient data and does not include a complete bibliographic crosswalk for its many original citation numbers. This article therefore uses 18 traceable external sources in place of reproducing unverified numerical claims. The review is targeted and narrative; it was not a registered systematic search and contains no independent meta-analysis or calculated diagnostic test accuracy. Some promising technologies—including AI and optical systems—have performance estimates that vary by population, data quality and validation approach [8,9,13]. The workflow is an original editorial integration model, not a tested intervention, and it should be prospectively assessed before any claim that its implementation improves caries outcomes or reduces treatment costs.

Future validation could enroll patients across three clinically distinct strata—early caries, erosive tooth wear and complex mixed wear—and record lesion status, risk exposures, functional symptoms, treatment choices and follow-up. Prespecified endpoints should include agreement between examiners, appropriateness of selected testing, lesion progression or arrest, change in patient-reported chewing difficulties, unplanned restorative retreatment and treatment acceptability. Such a study would allow the conceptual claims advanced here to be evaluated without conflating patient satisfaction, restoration survival and lesion-specific preventive success.

CONCLUSION

Dental hard-tissue disorders require a diagnosis that identifies not only the amount of tissue lost but also the processes that drive progression and the consequences most important to patients. The reviewed evidence supports structured visual-tactile examination, targeted bitewing imaging, individualized assessment of lesion activity and risk, and separate wear scoring when erosive or mechanical loss is suspected. Functional testing is useful in selected patients with symptomatic or complex rehabilitative needs, but should not be treated as a universal diagnostic requirement. An integrated, risk-adapted pathway can

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provide a transparent structure for prevention-first care, minimally invasive treatment and periodic reassessment. Its proposed clinical benefit remains a hypothesis requiring prospective testing.

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