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Comparative Review of Caries Indices for Clinical and Public Health Applications

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Abstract: ***Dental caries continues to be a widespread public health concern, necessitating the use of reliable indices for diagnosis, monitoring, and prevention. This review presents a detailed comparison of key caries indices, including DMFT, DMFS, dmft/dmfs, ICDAS, Nyvad Criteria, CAST, ADA CCS, PUFA, and SiC. Each index is evaluated based on its methodology, diagnostic scope, and contextual applicability in clinical and epidemiological settings. The review emphasizes the importance of selecting appropriate indices tailored to specific objectives, such as early detection, disease severity assessment, and identifying treatment needs in underserved populations. Ultimately, this synthesis aims to guide dental professionals and researchers in making informed choices for caries evaluation and intervention.***

Keywords: Dental caries, DMFT index, ICDAS, CAST index, PUFA index

1.Introduction

Dental caries remains a prevalent chronic disease worldwide, necessitating standardized tools for epidemiological assessment (1). The DMFT index, introduced in 1938 (2, 3), measures the cumulative burden of dental caries by counting the number of decayed (D), missing due to caries (M), and filled (F) permanent teeth in an individual's dentition. Its counterpart, the DMFS index, evaluates caries at the tooth surface level, offering enhanced sensitivity for detecting incremental changes in caries prevalence. Both indices are integral to clinical diagnostics, population-based surveys, and public health planning, as recommended by the WHO (4, 5). This review is significant in providing an updated, comparative overview of caries indices, aiding professionals in choosing suitable tools for diagnosis, surveillance, and treatment planning in diverse contexts.

DMFT Index

Methodology of the DMFT Index

The DMFT index is calculated as the sum of three components:

- Decayed (D): Teeth with untreated caries, characterized by cavitation, undermined enamel, or softened dentin, including primary caries or recurrent decay adjacent to restorations.
- Missing (M): Teeth extracted due to caries, excluding those lost for non-caries reasons (e.g., trauma, orthodontics).
- Filled (F): Teeth with restorations (fillings, crowns) due to prior caries.

Each tooth is counted once, with decay taking precedence over filled status if both are present. For example, an individual with 3 decayed, 2 missing, and 2 filled teeth has a DMFT score of 7. The maximum DMFT score is 28 (or 32 if third molars are included), assuming a full permanent dentition. Clinical examinations follow WHO guidelines, using a mirror and probe under adequate lighting, with teeth isolated for visibility (4). Radiographs are not routinely used, as the index prioritizes clinical detection for standardization, potentially underestimating caries prevalence (6). For populations, the mean DMFT is calculated by dividing the sum of individual DMFT scores by the number of individuals examined, yielding a decimal value.

Alternative Forms of the DMFT Index

- DMFS Index: The DMFS index assesses caries at the surface level, with molars and premolars having five surfaces and incisors/canines four. The maximum DMFS score is 128 for 28 teeth (148 with third molars). This index is more sensitive to subtle changes in caries prevalence but is complex to calculate, requiring detailed surface-level examination.
- dmft/dmfs Index (Primary Dentition) (7): For deciduous teeth, the dmft index (maximum score: 20) and dmfs index (maximum score: 88) use lowercase letters to denote decayed (d), missing due to caries (m), and filled (f) teeth or surfaces. Modifications include:
  - def Index: Used before exfoliation, where "e" indicates teeth requiring extraction due to caries.
  - df Index: Applied after exfoliation begins, excluding missing teeth to account for natural tooth loss.

These adaptations allow the indices to be applied across various age groups and dentition types, especially in pediatric populations.

Applications in Clinical and Public Health Contexts

The DMFT index is widely used to evaluate caries history, monitor disease progression, and guide treatment planning (restorations, extractions, or preventive measures like fluoride therapy). A lower DMFT score indicates better oral health, with scores approaching 0 reflecting minimal caries experience. In public health, the DMFT index informs epidemiological surveys, particularly for WHO-designated indicator groups (4, 5). Mean DMFT scores facilitate comparisons across communities, age groups, or regions, guiding policies such as water fluoridation, sealant programs, and oral health education. Global DMFT data highlight disparities in oral health. For example, a study in Tanzania reported a mean DMFT of 4.63 among adults, with 76.6% of individuals having a DMFT > 0 (8). In contrast, industrialized countries like Denmark report mean DMFT

scores as low as 0.9 for 12-year-olds, reflecting robust preventive measures (9).

Limitations of the DMFT Index

Despite its utility, the DMFT index has limitations (10):

- Lack of Disease Activity Assessment: It does not distinguish between active and arrested caries or capture non-cavitated lesions, potentially over- or underestimating caries burden in low-prevalence populations (4).
- Cumulative Nature: The index is irreversible, reflecting lifetime caries experience rather than current disease activity, which limits its utility for monitoring treatment outcomes.
- Equal Weighting: Decayed, missing, and filled teeth are equally weighted, despite differing clinical implications.
- Exclusion of Preventive Measures: The index does not account for sealants or other preventive interventions, which are increasingly common.
- Notably, the DMFT index lacks a standardized diagnostic threshold. It does not clearly define treatment needs or severity levels, which complicates clinical applications and limits nuanced data interpretation. Instead, it relies on visual detection of cavitated lesions at the dentin level, often underestimating early enamel caries and failing to align with principles of minimally invasive dentistry. This absence of a definitive threshold complicates its application in clinical settings, where more nuanced assessments are required, and introduces challenges in data analysis.
- Moreover, in different epidemiological studies, identical DMFT values can reflect markedly divergent oral health situations due to inherent limitations in the index's structure. For example, the DMFT assigns equal weight to untreated decayed teeth (D), missing teeth (M), and filled teeth (F), meaning a high score could indicate widespread active disease in underserved populations or, conversely, successful restorative interventions in areas with better access to care, without distinguishing between current disease activity and past experience. Variability is further compounded by examination conditions—epidemiological surveys using natural light and basic probes often underestimate caries prevalence by up to 40-60% compared to clinical settings with artificial light and diagnostic aids—and by differing diagnostic criteria, such as whether initial lesions are included, leading to inconsistent interpretations across studies and populations. These shortcomings underscore the need for supplementary indices, like ICDAS or CAST, to provide a more comprehensive view of caries epidemiology.

2.International Caries Detection and Assessment System (ICDAS)

The International Caries Detection and Assessment System (ICDAS) was developed to address this need, providing a systematic and universally applicable method for classifying caries based on their clinical presentation (11). Introduced in 2002 and refined through international collaboration, ICDAS categorizes caries on a 0–6 scale, capturing the full spectrum of disease progression from early, non-cavitated lesions to advanced cavitated lesions (12). Unlike traditional diagnostic approaches that often focused solely on cavitated lesions, ICDAS emphasizes early detection, enabling preventive interventions and more effective treatment planning (13).

The ICDAS framework is built upon a visual examination protocol that prioritizes the detection of caries at various stages of severity. The system employs a two-digit coding structure: the first digit indicates the restoration or sealant status of the tooth surface, while the second digit represents the caries severity score, ranging from 0 to 6 (13, 14). The scoring criteria are as follows:

- Code 0: Sound tooth surface with no evidence of caries after visual inspection, including air-drying to assess enamel integrity.
- Code 1: First visual change in enamel, indicating an early lesion visible only after drying, with no surface breakdown.
- Code 2: Distinct visual change in enamel, with localized enamel breakdown but no dentine involvement.
- Code 3: Localized enamel breakdown with underlying dentine shadow, suggesting caries progression into dentine.
- Code 4: Non-cavitated dentine caries with a clear shadow or discoloration beneath the enamel.
- Code 5: Cavitation exposing dentine, with a lesion confined to the outer half of the dentine.
- Code 6: Extensive cavitation penetrating deep into the dentine, often requiring restorative intervention.

This granular classification allows clinicians to differentiate between early, reversible lesions and advanced, irreversible caries, facilitating tailored treatment strategies. The system also incorporates standardized examination conditions, such as the use of air-drying and adequate lighting, to enhance diagnostic accuracy (13). The versatility of ICDAS makes it a widely adopted tool in both clinical and research settings. In clinical practice, ICDAS supports early intervention by identifying non-cavitated lesions that may benefit from preventive measures, such as fluoride application or remineralization therapies. By providing a standardized language for caries description, ICDAS enhances communication among dental professionals, improving treatment planning and patient education (15). In epidemiological studies, ICDAS enables precise comparisons of caries prevalence and severity across populations, informing public health policies and resource allocation.[16] In research, ICDAS has facilitated advancements in caries diagnostics, including the evaluation of new detection technologies and preventive strategies. Its compatibility with digital imaging and artificial intelligence-based diagnostic tools positions ICDAS at the forefront of modern caries research (16, 17).

Nyvad Criteria

The Nyvad Criteria is a clinical diagnostic system used in dentistry to assess caries lesions (tooth decay) based on their severity and activity (11). It is a visual-tactile method designed to provide a detailed and standardized approach to caries detection, classification, and management (13, 18).

The system relies on visual inspection and tactile examination (using a dental probe) to evaluate caries lesions (11). It assesses the surface characteristics of lesions, such as texture (smooth, rough, or hard), appearance (chalky, glossy, or discolored), and the presence or absence of cavitation.

Scoring System

The Nyvad Criteria uses a numerical scoring system (0–9) to classify lesions based on their characteristics:

- 0: Sound surface (no caries).
- 1–3: Non-cavitated lesions (ranging from active to inactive).
  - 1: Active, non-cavitated (e.g., white, chalky, rough surface).
  - 2: Inactive, non-cavitated (e.g., shiny, smooth, brownish surface).
  - 3: Active, non-cavitated lesion with localized surface breakdown (microcavitation).
- 4–6: Cavitated lesions.
  - 4: Active, cavitated (soft, rough base).
  - 5: Inactive, cavitated (hard, smooth base).
  - 6: Active, cavitated lesion with exposed dentin.
- 7–9: Filled surfaces (with or without caries activity adjacent to the restoration).
  - 7: Filled surface, no caries activity.
  - 8: Filled surface with active caries.
  - 9: Filled surface with inactive caries.

The system is designed for use in clinical practice, clinical trials, and epidemiological studies. It is particularly valuable for monitoring lesion dynamics over time, as it distinguishes between active lesions (requiring intervention) and inactive lesions (which may only need monitoring). It supports decision-making for non-operative (preventive) and operative (restorative) treatments by identifying lesions that are likely to progress versus those that are stable. The Nyvad Criteria emphasizes the importance of early detection and management of caries lesions, particularly non-cavitated lesions, which can often be managed with preventive measures like fluoride application, improved oral hygiene, or dietary counseling. By identifying active lesions early, clinicians can implement targeted interventions to arrest or reverse caries progression, reducing the need for invasive treatments.

Caries Assessment Spectrum and Treatment

The Caries Assessment Spectrum and Treatment (CAST) Index is a comprehensive epidemiological tool designed to assess the full spectrum of dental caries, from sound teeth to advanced stages involving pulpal and periapical complications (19, 20). It was developed to address limitations in existing caries assessment systems like the Decayed, Missing, and Filled Teeth (DMFT) index, the International Caries Detection and Assessment System (ICDAS), and the Pulpal Involvement, Ulceration, Fistula, and Abscess (PUFA) index (21). The CAST Index was introduced by Frencken et al. to provide a pragmatic and comprehensive caries assessment tool for epidemiological surveys (20). It was developed in response to challenges encountered when using ICDAS II and PUFA separately in a survey of Brazilian schoolchildren, where reporting results was cumbersome due to the lack of integration between these systems. The CAST Index combines elements of ICDAS (for early caries detection), PUFA (for advanced caries consequences), and DMFT (for compatibility with traditional metrics), creating a single, hierarchical index that captures the entire caries spectrum, including preventive measures (sealants), restorative treatments, and tooth loss (22). The term "Spectrum" reflects its key strength: the ability to describe caries progression from no lesions to severe stages, including pulpal involvement and tooth loss, in a structured and standardized manner. It is designed for use in epidemiological surveys and clinical settings, offering a practical approach to assessing caries prevalence, severity, and treatment needs (23).

The CAST Index uses a hierarchical coding system with 10 codes (0–9) to classify the condition of each tooth surface based on visual and tactile examination (22). The codes are ordered by increasing severity, with higher codes indicating more severe caries-related conditions. Below is a breakdown of the CAST codes:

- Code 0: Sound tooth (no caries, no sealant, no restoration).
- Code 1: Sealed tooth (preventive sealant applied, considered healthy).
- Code 2: Restored tooth (successfully restored due to caries, considered healthy).
- Code 3: Enamel caries lesion (non-cavitated, reversible premorbidity stage).
- Code 4: Non-cavitated dentine caries lesion (early dentine involvement, morbidity stage).
- Code 5: Cavitated dentine caries lesion (morbidity stage, restorable).
- Code 6: Caries with pulpal involvement (serious morbidity stage, often requiring endodontic treatment).
- Code 7: Caries with periapical involvement (abscess or fistula, severe morbidity stage).
- Code 8: Tooth lost due to caries (mortality stage).
- Code 9: Not recorded (unerupted teeth, trauma, or other non-caries-related conditions).

The CAST Index is primarily designed for epidemiological surveys but is also applicable in clinical settings. Its applications include:

- Caries Prevalence and Severity: The CAST Index allows for detailed documentation of caries prevalence, including early lesions (Code 3), cavitated lesions (Codes 4–5), and severe outcomes (Codes 6–8).
- Treatment Needs Assessment: CAST categorizes teeth into treatment need categories (24):
  - Codes 0–2: No treatment required (healthy dentition).
  - Code 3: Preventive treatment (e.g., fluoride application).
  - Codes 4–5: Restorative treatment (fillings).
  - Code 6: Endodontic treatment (root canal therapy).
  - Code 7: Endodontic treatment or extraction.
  - Code 8: Replacement (prosthodontics or implants).

3.American Dental Association Caries Classification System

The American Dental Association Caries Classification System (ADA CCS) is a standardized framework developed by the American Dental Association (ADA) Council on Scientific Affairs to assess and classify dental caries lesions in clinical practice (25). It is designed to support clinical decision-making by providing a comprehensive, practical, and evidence-based approach to caries diagnosis, treatment planning, and monitoring (25). The ADA CCS classifies caries lesions by anatomical location, origin, extent, and activity, covering the full spectrum from sound tooth structure to advanced cavitated lesions.

The ADA CCS was introduced in 2015 to address the need for a unified, practical caries classification system that aligns with modern principles of minimally invasive dentistry and personalized patient care. The ADA CCS classifies caries lesions based on four key characteristics: location, site of origin, extent, and activity. Each aspect is systematically evaluated to provide a detailed description of the lesion, which informs treatment decisions.

- Location: Lesions are categorized by their anatomical location on the tooth:
  - Pit and Fissure: Lesions in occlusal surfaces, buccal/lingual grooves, or other pitted areas.
  - Proximal (Contact) Surfaces: Lesions on mesial or distal surfaces, typically detected radiographically or clinically.
  - Cervical/Gingival: Lesions near the gingival margin, often associated with root exposure or poor oral hygiene.
  - Root Surface: Lesions on exposed root surfaces, common in older adults with gingival recession.
- Site of Origin: This refers to the specific tooth surface where the caries process begins:
  - Enamel: Lesions originating in enamel (common in early caries).
  - Dentin: Lesions extending into dentin, often indicating progression.
  - Cementum: Lesions on root surfaces, typically in areas of exposed cementum.
- Extent: The extent of the lesion describes its depth and severity, categorized into four stages:
  - Sound (S): No clinical or radiographic evidence of caries.
  - Initial (I): Early lesions confined to enamel or outer dentin, often non-cavitated or with minimal surface breakdown (e.g., white spot lesions or microcavitation).
  - Moderate (M): Cavitated lesions involving dentin but not approaching the pulp, typically restorable with direct restorations.
  - Advanced (A): Deep cavitated lesions with potential pulpal involvement, often requiring complex restorative or endodontic treatment.
- Activity: When possible, lesions are assessed for activity to determine their likelihood of progression:
  - Active: Lesions with a chalky, rough, or soft surface, often whitish or opaque, indicating ongoing demineralization and a higher risk of progression.
  - Inactive/Arrested: Lesions with a smooth, shiny, or hard surface, often brownish or black, indicating remineralization or stability.

Activity assessment is based on visual-tactile criteria (similar to the Nyvad Criteria) and may incorporate patient risk factors (e.g., diet, oral hygiene, saliva flow). However, activity assessment is noted as "when possible" because it can be challenging to determine definitively in some clinical scenarios. The ADA CCS does not use a numerical scoring system like the Nyvad Criteria (0–9) or CAST Index (0–9). Instead, it employs a descriptive approach, combining abbreviations for each characteristic. For example, a lesion might be documented as "Proximal, Enamel, Initial, Active" (P-E-I-A) or "Pit and Fissure, Dentin, Moderate, Inactive" (PF-D-M-I).

PUFA Index (Pulpal involvement, Ulceration, Fistula, Abscess)

PUFA records the presence of severe consequences of untreated caries: visible pulpal involvement, ulceration from tooth fragments, fistula, and abscess (26, 27). It complements classical indices by quantifying the clinical consequences of untreated caries, especially in populations with high untreated caries rates. It is reliable and easy to use, but does not assess early or moderate caries (26, 27). The PUFA Index categorizes four distinct clinical conditions per tooth, assessed through visual inspection and recorded based on the most severe condition present. The conditions are defined as follows:

- P (Pulpal Involvement): Caries penetrating the pulp, resulting in inflammation or necrosis.
- U (Ulceration): Soft tissue ulceration caused by trauma from sharp carious tooth fragments.
- F (Fistula): A pus-draining tract associated with a carious tooth.
- A (Abscess): A pus-containing swelling linked to a carious tooth.

Each tooth is assigned a single PUFA code (P, U, F, or A), reflecting the most severe condition observed. The index does not score individual tooth surfaces, ensuring simplicity in data collection. Results are reported as:

- PUFA Score: The number of teeth exhibiting each condition.
- Prevalence: The percentage of individuals with at least one PUFA condition.
- Mean PUFA: The average number of affected teeth per individual in the surveyed population.

It is primarily utilized in population-based oral health assessments to measure the burden of untreated caries, particularly in low-resource settings or pediatric populations. Its clinical relevance lies in identifying teeth requiring urgent interventions, such as endodontic treatment or extraction, thereby guiding prioritized care delivery. The index is applicable to both primary and permanent dentitions and is widely used in community-based oral health programs to evaluate unmet treatment needs.

Significant Caries Index (SiC)

SiC is the mean DMFT of the one-third of the population with the highest caries scores.[28] It highlights caries polarization and is useful for identifying high-risk groups in populations with declining caries prevalence (28). However, in populations with very low prevalence, SiC may include caries-free individuals, limiting its discriminatory power (29). The Significant Caries Index (SiC) is an epidemiological metric designed to highlight caries polarization by focusing on the subset of a population with the highest caries burden. To address the limitations of the traditional DMFT index—particularly in populations with declining caries rates—the SiC was introduced to highlight high-risk subgroups. In populations with declining caries prevalence, the DMFT mean can mask significant disparities, as many individuals may be caries-free while a minority experience a high caries burden. The SiC focuses on the one-third of the population with the highest DMFT scores, providing a targeted measure to identify high-risk groups and guide public health interventions.

The SiC is calculated by:

- Ranking individuals in a population by their DMFT scores (from highest to lowest).
- Selecting the top one-third (highest caries experience).
- Computing the mean DMFT for this subgroup.

For example, in a population of 300 individuals, the 100 individuals with the highest DMFT scores are selected, and their average DMFT is calculated as the SiC. The SiC value is always higher than the overall mean DMFT, reflecting the caries burden in the most affected subgroup.

4.Conclusion

Caries indices are critical tools for assessing dental caries in clinical practice, epidemiological research, and public health planning. The DMFT and DMFS indices provide a simple, standardized measure of caries experience, while the ICDAS and Nyvad Criteria offer detailed assessments of lesion severity and activity, enabling early intervention. The CAST Index provides a comprehensive spectrum of caries stages, from prevention to severe outcomes, and the ADA CCS supports minimally invasive dentistry through its descriptive classification. The PUFA Index highlights severe caries consequences, particularly in underserved populations, and the SiC identifies high-risk groups in populations with declining caries prevalence. Each index has unique strengths and limitations, and their selection depends on the specific clinical or research objectives, such as early detection, treatment planning, or addressing unmet treatment needs.

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