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PERSPECTIVE

Principles and care pathways for caries management in children: IAPD Rome forum

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1 | INTRODUCTION

The traditional approaches to the treatment of dental caries have focused on repairing the consequences of the caries process, the lesions, rather than addressing the disease process itself. Advances in the understanding of caries microbiology, de-/remineralization cycling, risk/susceptibility assessment, staging of lesion activity/severity, non-surgical/micro-/minimally invasive procedures and public health interventions are fundamentally changing the landscape of caries management. To facilitate the global adoption of contemporary caries management for children, international experts were convened as part of an International Association of Paediatric Dentistry (IAPD) forum in Rome, in November 2022. This expert panel met for a one-day pre-conference workshop to discuss and consider principles of cariology and care pathways to improve oral health for individuals and healthcare systems. The topics discussed included advances in the science of cariology, advances in caries management, improving oral healthcare systems and teaching caries management. Such advances are especially important for children's oral health because of the value of establishing early preventive behaviours (including caregivers), difficulties of performing procedures in young children and inequalities/inequities in children's oral health care. The topics were presented over the two-and-a-half-day congress, and the feedback was collected. This position paper presents the summarized evidence collated by the expert panel and the IAPD Board of Directors.

2 | ADVANCES IN THE SCIENCE OF CARIOLOGY

2.1 | Microbiology, remineralization and fluoride

Dental caries is a chronic disease caused by the chemical loss of tooth structure from the metabolic activity of the microbial biofilm that covers the tooth surface. Advances in technology are improving the understanding of microbiome composition, function and spatial structure, showing that the oral bacterial communities are less diverse in advanced carious lesions and may include fungal species.[1,2] This evolving understanding includes a 'rotund' microbial organization in some caries-active patients, having an inner core of mutans streptococci encompassed by outer layers of other bacterial species[3–5] (Figure 1). These rotund communities create localized highly acidic (pH 4.0–4.5) 'virulence hotspots' at the biofilm/tooth interface that is associated with enamel demineralization.

The virulence hotspots may have alternating periods of de- and remineralization, with a predominance of demineralization over time if environmental cariogenic conditions persist. Remineralization cycles, particularly in the presence of fluoride, however, form a fluoride-rich surface layer on the enamel lesion. Under a cariogenic challenge, the fluoride-rich enamel surface may remain mostly intact, with the continuing dissolution of hydroxyapatite in the subsurface. Although the fluoride-rich surface layer

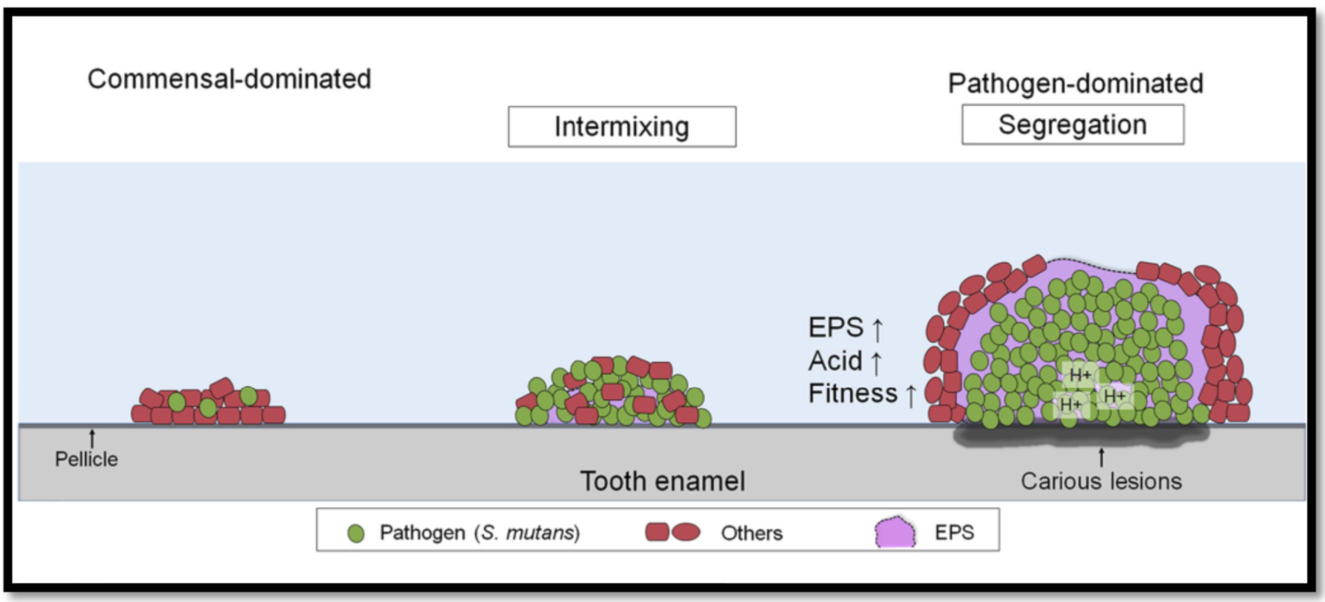

FIGURE 1 Rotund bacterial community structures on the teeth, with an inner core of mutans streptococci encompassed by outer layers of other bacterial species, are frequently detected in some caries-active patients (reproduced from Kim et al. PNAS 2020;117:12375–12386[44]; https://creativecommons.org/licenses/by/4.0/).

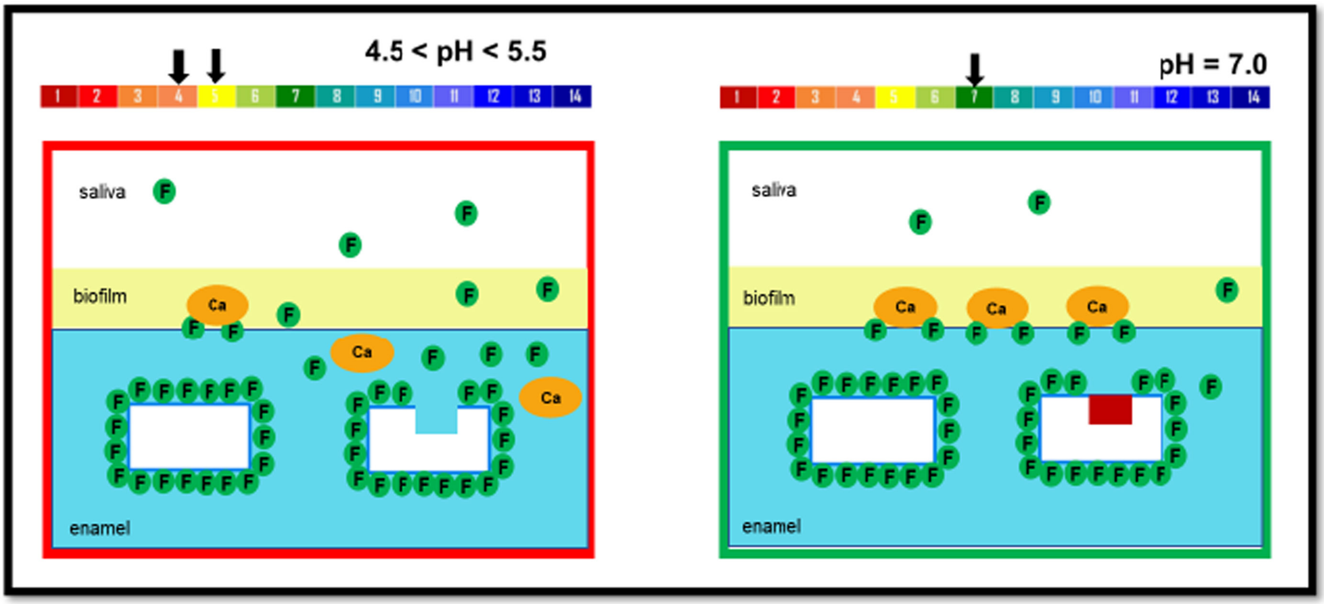

FIGURE 2 Mode of action demineralization and remineralization. Under a cariogenic challenge (left), calcium fluoride deposits dissolve releasing calcium and fluoride. The fluoride released diffuses to the enamel fluid and adsorbs to the hydroxyapatite crystals inhibiting demineralization. After an acidic challenge (right), the presence of low levels of fluoride allows for the precipitation of fluoridated apatite (red), which resists future acidic challenges.

reduces the diffusion of demineralizing agents into the lesion, it also makes remineralization of the lesion body more difficult.[6] The fluoride that is released during demineralization diffuses to the enamel fluid and is adsorbed to the hydroxyapatite crystals, making the crystals less soluble, thus inhibiting further demineralization. With a pH >5.5, saliva is supersaturated with mineral, and remineralization will naturally occur, allowing the precipitation of fluoridated apatite over the partially dissolved crystals. This newly formed mineral also is more resistant to future acidic challenges[7] (Figure 2).

The main mechanism of action of fluoride is topical, including delivery methods such as fluoridated water and professionally applied varnish. Fluoride primarily acts by initial contact with the teeth, and when fluoride returns to the oral cavity by means of saliva. High-concentration fluoride levels, such as with topical treatments, produce reservoirs in the dental biofilm and on the enamel surface, as calcium fluoride. With an acidic challenge, the reservoirs release fluoride that subsequently affects the de- and remineralization balance.[7] The exclusion of carbonate in the enamel crystal structure and the inclusion of fluoride cause the remineralized subsurface layer to be less soluble than the original mineral and more resistant to future acidic challenges.[7,8]

2.2 | Evidence-based care

Evidence-based care is informed by the best available high-quality evidence evaluated in the context of desirable and undesirable effects, costs, resources, feasibility, applicability and patient values/preferences. The desire to provide person-focused, evidence-based care has led to a journey away from the traditional 'drill-fill-bill' approach to exploring concepts of holistic, personalized health management. The care pathways for caries management include approaches for caries prevention, non-restorative strategies, minimally invasive strategies and traditional restorative strategies, all supported by varying levels of evidence in the literature (Figure 3). The choice of strategies for children depends on factors such as caries risk/susceptibility, the ability of the family/caregiver to adopt preventive behaviours for the child, the cognitive age/abilities of the child, extent/activity of carious lesions and overall prognosis.

The extent and activity of the caries process should determine appropriate preventive strategies. Primary preventive strategies (actions that are taken to stop a disease from occurring) include regular mechanical disruption of the dental biofilm to combat virulence hotspots, twice-daily fluoride exposure, preventive fissure sealants and professional fluoride applications, which are supported by evidence from numerous clinical trials and meta-analyses. Strategies related to water fluoridation, dietary recommendations and anticipatory guidance have less evidence from clinical trials but should be considered best pragmatic practice. Secondary preventive strategies (actions that halt or slow the progression after disease is apparent) target non-cavitated and cavitated lesions with either non-invasive or micro-/minimally invasive strategies aimed at arresting

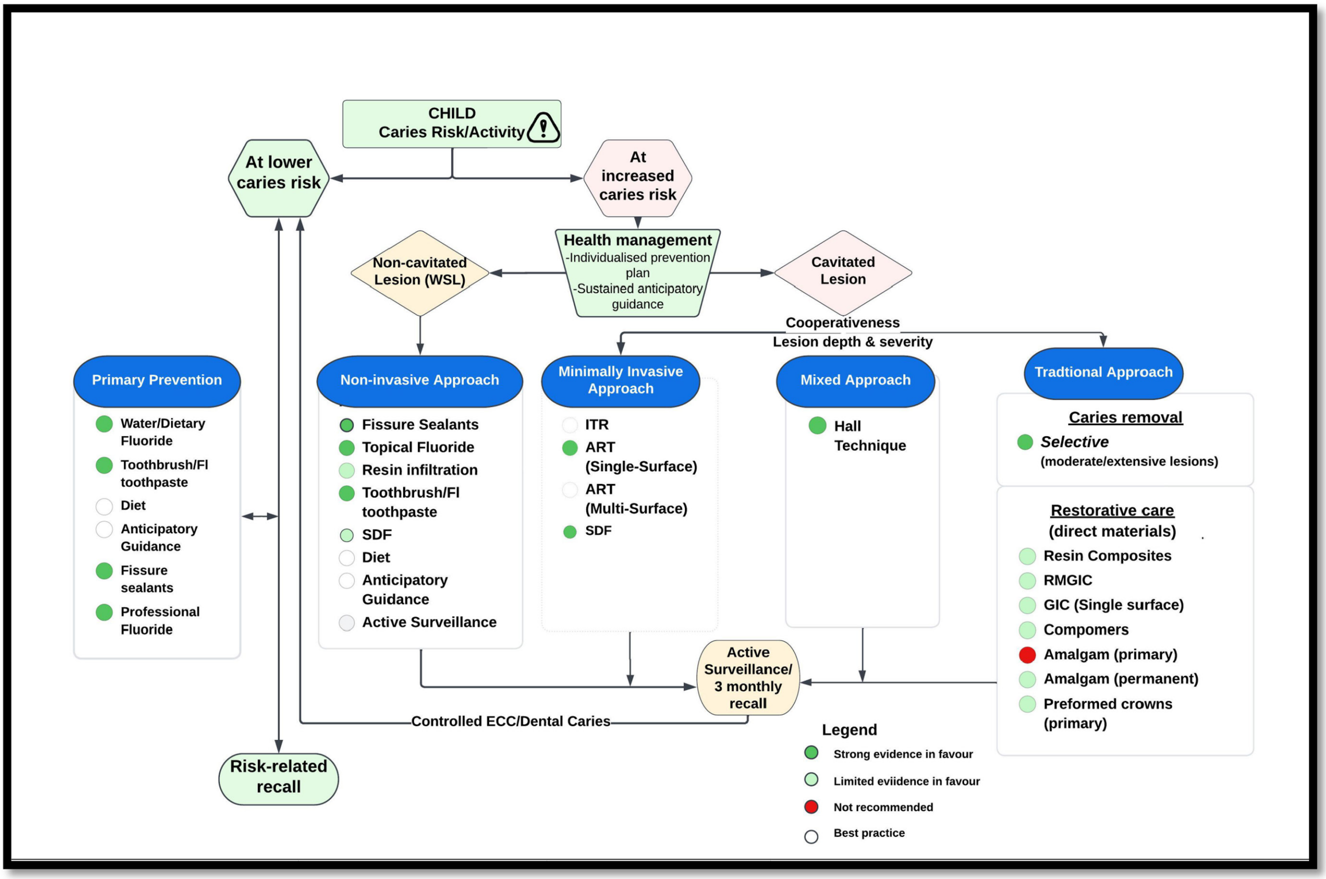

FIGURE 3 Levels of evidence from 'strong evidence in favour' to 'not recommended' for care pathways for caries management in children from practice guidelines, systematic reviews and expert opinion.

lesion progression, such as silver diamine fluoride, professional fluoride applications and atraumatic restorative treatment. These practices are supported by evidence from numerous clinical trials and meta-analyses. There is growing evidence to support secondary prevention techniques with resin infiltration and no/selective caries removal of extensive lesions followed by a Hall crown restoration. Tertiary prevention of cavitated, active and non-cleansable carious lesions can involve both non-invasive and minimally invasive preventive approaches. There are many restorative dental biomaterials for single-surface and multiple-surface lesions, as well as for direct and indirect restorations. There is, however, a paucity of evidence assessing the comparative effectiveness of these materials.[9]

2.3 | Caries risk/susceptibility assessment (CRSA)

Many risk/susceptibility assessment procedures used in medical practice have sufficient data to accurately quantify a person's disease susceptibility and allow for effective targeting of preventive measures. Nevertheless, in dentistry, most caries risk/susceptibility assessment (CRSA) tools that determine individuals at low or elevated risk for dental caries progression still lack broad validation.[10] Nevertheless, CRSA currently has value to caries management since (1) it results in an understanding of the caries risk/susceptibility and protective factors for a specific patient, allowing for the identification of factors that are modifiable; (2) it fosters the management of the disease process instead of focusing on treating the outcome of the disease; (3) it can help determine a person-specific prognosis and personalized care pathway, thus helping to anticipate caries progression or stabilization; and (4) it can help guide appropriate recall intervals and periodicity of interventions.

Most structured CRSA tools use three or more categories or levels of risk (i.e., low, moderate and high). From a research perspective, it has not been possible to consistently separate patients into more than two risk categories (low risk vs. elevated risk).[11] Established tools allow longitudinal comparison, which is important as children may shift risk categories especially at pivotal ages such as at eruption of primary teeth, first molars and second primary molars. Furthermore, in practice it is sufficient to focus on identifying patients at the ends of the risk spectrum because those at 'low risk' and those at 'elevated risk' of caries progression have clear distinct management needs.[12] Effective CRSA can potentially help improve health outcomes and reduce costs through targeted, personalized prevention and intervention.

2.4 | Shared decision-making

Globally, there is a shift from providing acute problem-focused medical and dental interventions to providing sustainable, holistic (integrated) preventive health care. Holistic health care implies focusing on the main complaint, as well as the physical, social, emotional, cultural, sensory, cognitive and communication needs and abilities. Shared decision-making (SDM) complements holistic health care and plays a crucial role in person-centred caries management pathways.

Shared decision-making requires the oral healthcare provider and the patient/caregiver to give assent/ agreement on a care management pathway.[13] This mutual agreement is reached after the treatment options, and probable outcomes and patient preferences are fully considered and discussed.[14] Shared decision-making is inseparable from informed consent/assent but refers more to the entire process of patient education, motivation and interaction with the oral healthcare team providers. Charles et al. (2016) described the process of SDM in three separate stages, labelled as 'information exchange', 'deliberation' and 'deciding on treatment to implement'.[13]

Although SDM is researched and supported by the literature, barriers in this process such as poor-quality information about conditions and treatment options, inappropriately tailored treatment options to the child and family's health literacy and being too time-consuming to perform have been identified.[14] Well-developed patient decision aids may assist in overcoming perceived barriers in SDM, by assisting practitioners to provide patients with evidence-based information in lay terms to trigger conversation and questions. Figure 4 is an example of a SDM model, covering the key concepts of the process as well as the roles and responsibilities of the dentist, caregiver and child/patient.

2.5 | Active surveillance

Active surveillance, that is, applying preventive and/or non-operative measures and monitoring for signs of disease arrest or progression, is based on the concept that restorative dental care should only be necessary if there is a significant advancement of caries. The justification for this approach in

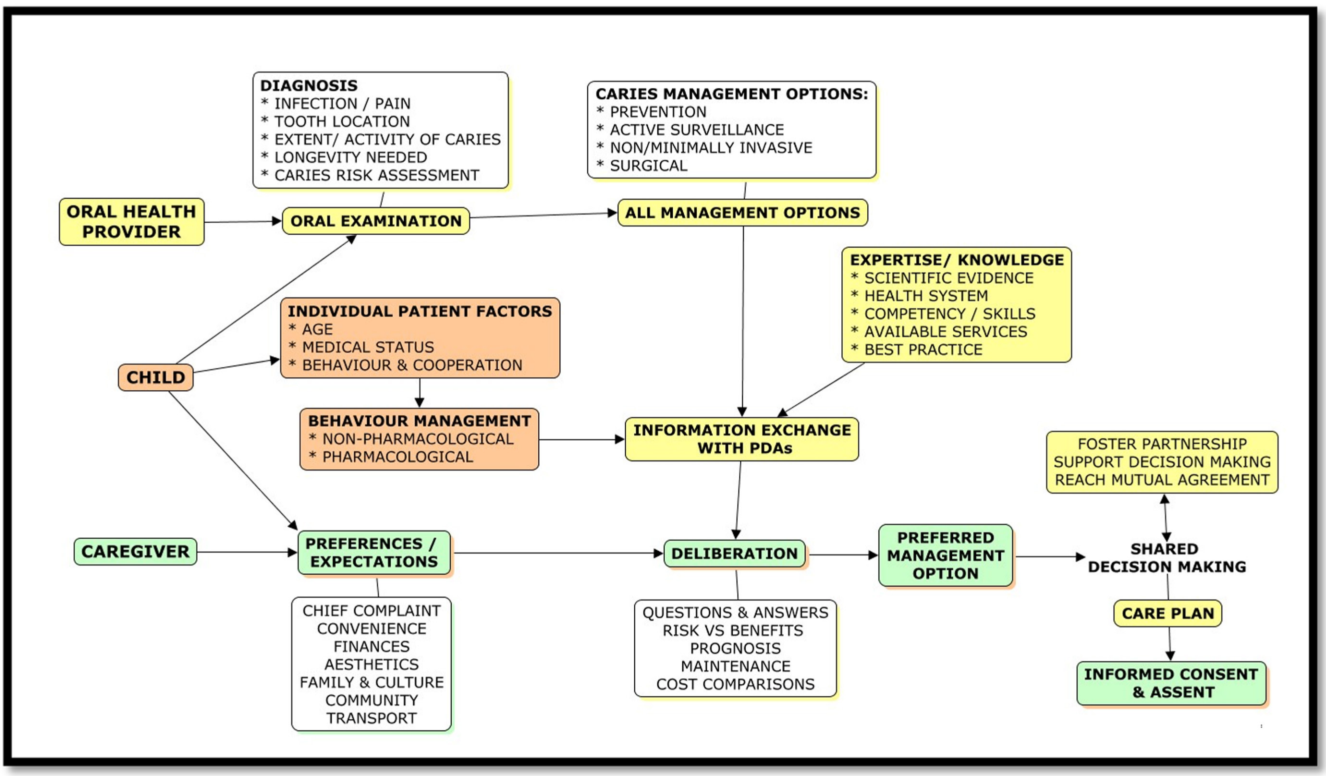

FIGURE 4 Example of a shared decision-making model for children's oral health (adapted from reference[45]) incorporating key concepts, as well as the roles and responsibilities of the oral health provider, caregiver and the child/patient at the centre.

oral health can be derived from data showing a substantial percentage of lesions on primary teeth that do not progress over time.[15] Deferring invasive caries management on initial and minimal lesions involves SDM with the caregiver/child, determining the caries severity/activity of existing lesions, the caries risk/susceptibility of the child, evaluating the efficacy of preventive/non-operative strategies being used, and the fidelity to periodic recalls to assess lesion arrest or progression IAPD, AAPD.[16,17]

3 | ADVANCES IN CLINICAL CARIES MANAGEMENT FOR CHILDREN

The concept of 'caries management pathways' in contrast to 'dental treatment plans' is critical to the contemporary person-focused management of dental caries, since clinical pathways yield a greater probability of success, fewer complications and more efficient use of resources.[18] An example of clinical caries management was suggested by Ismail and others in 2015 that emphasized the following: (1) staging lesion severity and activity; (2) assessing patient's caries risk/susceptibility status; (3) synthesizing data leading to diagnosis; (4) comprehensive caries care planning including prevention, non-operative management and tooth-preserving operative management; and (5) evaluating outcomes including further management and recall frequency.[19]

Primary caries management/prevention for children should begin before the initiation of disease. The evidence-based pillars for primary prevention are twice-daily toothbrushing using a fluoride-containing toothpaste, limited intake of free sugars[20,21] and dental sealants where necessary.[22] If primary prevention fails, secondary prevention needs to target early carious lesions with advances in minimally invasive strategies, such as professionally applied fluoride and high-fluoride (1.1% NaF) toothpaste for children over age six.[23] Advanced cavitated lesions may be less likely to be arrested, thus requiring operative approaches. In addition to the many advances in caries management, it is important that they conform to SDM, patient preferences, local/regional standards and government/healthcare policy regulations.

Pulp therapy in the primary dentition aims to preserve the teeth until they exfoliate naturally. In young permanent dentition, pulp therapy aims to preserve pulp sensibility and allow root development to continue. For both primary and permanent teeth, selective caries removal is an advance in caries management to prevent pulp exposures by excavating to hard dentine on the peripheral walls of deep lesions while leaving leathery (or in some cases, soft dentine) on the pulp floor.[24] There is a fundamental need to increase oral health providers' awareness of selective caries removal techniques for the management of deep carious lesions.

4 | IMPROVING ORAL HEALTH SYSTEMS

4.1 | Reducing inequalities and inequities

Globally, more than 500 million children suffer from caries of primary teeth.[25] Despite the recognition of oral health as a human right, children throughout the world face inequalities in oral health care. Children living in underserved communities are less likely to visit oral healthcare providers, even if available, and often have unhealthy habits and/or lack family health literacy.[26] The age of a child is also a key factor regarding inequities because oral healthcare providers may often elect not to see children, especially pre-schoolers. Children younger than 4 years are often pre-cooperative; children older than four years may have situational anxiety or fear, often passed on from relatives/caregivers, which engenders behavioural difficulties with treatment.[27] Children with special healthcare needs also experience inequities due to lack of access to facilities and the necessity for providers with specialist training.[28]

The goal of optimal oral healthcare delivery should be to offer the same high-quality care irrespective of barriers.[29] Primary prevention is a cost-effective public health measure that can have an impact on reducing oral health inequity irrespective of social status.[30] Integrating primary-associated medical providers into oral health care can help to increase children's access to early preventive examinations and, when necessary, referral for oral and dental care.[31] Partnerships for school-based oral examinations and oral hygiene instruction also should be encouraged for socially disadvantaged communities.[32] In many countries, practitioners may need to provide treatment in non-traditional settings that restrict treatment options and may not allow for follow-up care.

4.2 | Reimbursement systems

Oral diseases are a main driver of increased health expenditures, particularly for poorer and marginalized groups.[33] Problems include lack of/inadequate oral healthcare systems in many countries, under-utilization of extended providers and counterproductive professional remuneration systems. Room for improvement exists in the design of oral health benefit packages to ensure that all people have access to essential, quality oral health care that corresponds to their needs and can be used without suffering financial hardship.[34]

Provider remuneration has a substantial impact on access to care. Fee-for-service payments have been criticized as generating high volumes of interventive treatments and having a limited impact on incentivizing preventive care.[35] Capitation payment plans and performance/outcome provider payment systems have been proposed as potential alternatives for provider remuneration.[36] A study that compared fee-for-service with capitation plans for oral health care in children found that in a capitation system, teeth were restored at a later stage, providers tended to see their patients less frequently and performed fewer restorations and extractions; yet, the capitation plans tended to offer more preventive advice.[37] Since individuals in lower socio-economic settings often have higher disease risks and needs, capitation plans also have been associated with barriers to access for care.[35,36] Examples of performance/outcome provider payments in the United States and disease risk–adjusted recall intervals in Denmark also highlight the challenges with the measurement of outcomes to assess provider performance or dental disease risk, which are perceived to be overly complex.[38,39]

5 | TEACHING CARIES MANAGEMENT

The advanced knowledge of oral health care for children compels the movement from a surgical care model to an oral health outcome model. This transformation has consequences for the way the profession is educated, integrated across a dental school's curricula and how students' learning and competencies are assessed/evaluated.[40,41] Person-focused, evidence-based cariology curriculum frameworks have been developed and adapted to different parts of the world for use in dental education.[42,43] Approaches to implement health outcome model will need to include the training and calibrating of oral health educators on evidence-based caries management; integrating caries management with other disciplines; and establishing clinical competencies in patient assessment, behavioural science and caries management. The oral health outcome model will prepare new practitioners for the future, which includes patients at the centre of preventive oral health management.

AUTHOR CONTRIBUTIONS

NT initiated a panel to advance the principles and care pathways. MB, VD, MF, NI, HK, SL, NP, FS, ST and KV contributed to the initial drafts. All authors reviewed and critically revised the manuscript drafts. All authors read and approved the final manuscript.

CONFLICT OF INTEREST STATEMENT

No authors claim any conflicts of interest with this manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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