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Dental Caries in Latin American and Caribbean countries: urgent need for a regional consensus

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Dental caries, a biofilm-mediated, sugar-driven, dynamic disease, affects a considerable proportion of children and adults worldwide. Recent reports indicate that the global burden of untreated dental caries for primary and permanent dentition is high in several countries and has remained relatively unchanged over the past 30 years.[1,2,3]

There is no doubt that Latin American and Caribbean countries (LACCs) are equally impacted by the burden of dental caries. However, to date, this area of the globe has never discussed dental caries in a comprehensive manner from a regional perspective. Many researchers have ignored the fact that Latin America is the most urbanized region in the world with severe social inequalities.[4] Moreover, LACCs are responsible for approximately half of the global sugar production as well as known for their high sugar consumption.[5] These aspects indeed impact the prevalence of dental caries in many parts of the continent, although salt and water fluoridation has been implemented in some areas of the region and fluoride dentifrice is available for a considerable part of the population.[6]

The Latin American Oral Health Association (LAOHA) is a nonprofit organization that has the following aims: a) foster the development of new researchers, b) influence oral health policy in the region, c) support the dental profession via education and exposure to new advances in dentistry, and d) encourage research initiatives in Latin America. Based on these principles, LAOHA established and mobilized a local network of experts in Cariology, Public Health, Epidemiology, Pediatric Dentistry, Restorative Dentistry, and other fields to explore dental caries in the following four domains: a) dental caries epidemiology and its impact on Oral Health Related Quality of Life, b) dental caries risk factors,[7] c) dental caries preventive strategies,[8] and d) dental caries (restorative) management.[9] For each domain, an expert and the coauthors were asked to investigate reports, publications, and research on dental caries considering the complexity of the LACC environment and challenging strategies for tackling the problem.

In brief, the first draft of an article for each of the four domains was written during the first term of 2020 and reviewed by several invited experts from LACCs and the board members of international and regional dental associations. Later, these draft articles were presented and discussed in a virtual mode during the IADR (International Association for Dental Research) Brazilian meeting in September 2020. Several new points of discussion and suggestions from this meeting were incorporated

in the second version of the article. Then, the final versions of the articles were shared for a second round of review by the same as well as new experts. Meanwhile, a fifth article presenting the summary as well as general and specific recommendations was also prepared and revised.[10]

The five articles were finally presented in November 2020 in the virtual consensus meeting held in Mexico, titled "*Dental caries prevalence, prospects, and challenges for Latin American and Caribbean countries: A regional consensus*." Following the meeting, a final review was performed by more than 110 stakeholders and experts from 22 countries enrolled in this initiative to achieve a consensus.

This consensus is a great achievement for LAOHA and all authors, reviewers, dental associations, and collaborators of this project. This special issue of *Brazilian Oral Research* was written in English. Moreover, Spanish and Portuguese versions will be available as e-books. It represents a year of challenging work that was completed in a virtual mode because of the coronavirus disease 2019 pandemic that imposed a virtual existence and changed the way we meet. This new scenario has brought both opportunities and challenges for LACCs with respect to future epidemiological surveys, dental assistance, and clinical and experimental studies.

Dental caries is preventable, and some international organizations have indicated potential solutions and recommendations.[11-14] This raises the question why there is no substantial positive impact on reducing caries and inequalities in oral health in LACCs. These and other points of reflection are discussed in all papers of the consensus. We hope that this consensus will be regarded as "the end of the beginning." We believe that this would be a starting point for LACCs to reduce gaps in our epidemiological data on dental caries and thereby implement synchronized, well-planned regional actions that will make a difference and reduce the burden of dental caries in this part of the world in the near future.

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Dental caries experience and its impact on quality of life in Latin American and Caribbean countries

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Abstract: Robust epidemiological data allow for logical interventions taken in the interest of public health. Dental caries is a major public health problem driven by increased sugar consumption and various biological, behavioral, and psychosocial factors, and is known to strongly affect an individual's quality of life. This study aims to critically review epidemiological data on the prevalence of dental caries in Latin American and Caribbean countries (LACC) and its impact on the oral health-related quality of life (OHRQoL) of the population. Although the majority of national surveys did not include all age groups and several countries reported a reduction in the prevalence of cavitated carious lesions, most nations still exhibited a high burden of decayed teeth. OHRQoL evaluation was limited to children and older adults only, and was not included in any national survey. Study heterogeneity and methodological issues hindered comparison of evidence between studies and over time, and updating national level data on caries prevalence and its impact on OHRQoL should be prioritized in LACCs.

Keywords: Dental Caries; Epidemiology; Quality of Life; Latin America; Caribbean Region.

Introduction

Epidemiological survey data is useful for the prevention, control, and eradication of various health problems, serving as an essential tool for development of public policy and planning of interventions aimed at promotion of health.[1] Oral health plays a crucial role in the well-being of a population and, when compromised, can affect an individual's quality of life by causing pain and loss of esthetics/function leading to absenteeism from work/schools and low self-esteem.[2] The dental caries pandemic is driven by an increase in the consumption of refined sugars and changes in eating patterns and social behaviors.[3]

Untreated carious lesions are one of the most frequently observed oral health problems globally, with prevalence rates being 100% and 80% among 12 year old adolescents in low-income and lower-middle-income countries, respectively.[4] Moreover, such lesions often persist into adulthood, with disease burden increasing with the number of teeth in the oral cavity. The global burden of untreated caries lesions in permanent teeth

was 2.3 billion people, and regarding untreated caries in primary teeth, 532 million children were affected worldwide.[5]

However, the prevalence of dental caries has decreased in several countries, resulting in polarization of the disease and higher rates being observed among deprived populations.[6,7] The last two decades of the 20th century and the first two decades of the 21st century were characterized by massive structural, demographic, and social changes in developing countries [particularly Latin American and Caribbean countries (LACC)], with intense urbanization, progression of the population demographic to increased life expectancy and higher proportions of elderly individuals, and changes in nutritional patterns to include increased intake of calorific, industrialized, and ultra-processed foods resulting in higher prevalence of obesity, compromised quality of life, and variations in the way diseases affected populations.[8]

Dental caries management can prove to be challenging, particularly in developing countries that exhibit higher disease prevalence.[5,9] A systematic review and meta-analysis of studies examining children aged 5–6 years and adolescents aged 11–13 years in LACCs concluded that more than 50% of the study population exhibited dental caries.[10] In fact, the tropical Latin American region was shown to exhibit the highest prevalence of untreated dental caries in the world.[11]

However, there is limited data available on the older populations in this region, and this information is particularly important when considering the demographic transition occurring in Latin America. The Survey of Health and Well-Being of Elders carried out among adults aged 60 years and above from seven cities in LACCs showed that approximately 97.5% of the participants had lost their teeth (although these rates were lower among those with higher educational attainment) and exhibited greater need for dental treatment.[12]

Dental caries is a socially determined disease and is directly affected by various behavioral, social, and demographic factors,[7,13] and the management of this disease by individuals, health professionals, and public managers can substantially affect the patient's quality of life.[14] The Oral Health-Related Quality of Life (OHRQoL) is a multidimensional, complex, and dynamic construct formed by a subjective evaluation of how oral health can impact an individual's functional and emotional well-being and their expectations of and satisfaction with care and the sense of care.[15] Therefore, OHRQoL is subject to changes over time and is also sensitive to the social, cultural, and political context.[16]

Dental caries can negatively affect OHRQoL in different age groups, with developing countries and underprivileged populations being the worst affected. Poor oral health can negatively affect an individual's ability to perform essential activities, such as chewing, speaking, smiling, limit their ability to attend work/school and compromise their psychological well-being.[17] The oral health of an individual plays a crucial role in their overall general well-being and is considered to be an important determinant of their quality of life.[18]

Evaluation of the prevalence of dental caries in LACCs and its impact on OHRQoL is essential as it can provide an evidence base for policymakers, dental professionals, and individuals committed to the improvement of oral public health in these countries through the implementation of effective prevention and health promotion measures.[19] Therefore, this study aims to critically review epidemiological evidence on the prevalence of dental caries in LACCs and its impact on the population's OHRQoL.

Methodology

Search strategy

Studies on the prevalence of dental caries in LACCs were identified through systematic searches conducted on the following databases: MEDLINE, EMBASE, LILACS, and Google Academic. Additionally, the World Health Organization Dental Databank and the official LACC Ministry of Health websites were also searched. Manual searches were carried out using the Medical Subject Heading descriptor "*Dental Caries*", the qualifier "*Epidemiology*", and the key words "*dental treatment needs*" and "*oral health surveys*" combined with the terms "*Latin America and the Caribbean*" and "*Central America and South America*". Additionally, individual

country names, including Mexico in North America; Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama in Central America; Antigua and Barbuda, Aruba, Bahamas, Barbados, Bonaire, Cayman, Dominica, Dominican Republic, Guadalupe, Haiti, Jamaica, Saint Lucia, Saint Kitts and Nevis, Saint Martin, Saint Vincent and Grenadines, Island Grenada, Navassa Island, Saba, Nueva Esparta, Puerto Rico, Trinidad and Tobago, and Turks and Caicos in the Caribbean; and Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, French Guiana, Guiana, Paraguay, Peru, Suriname, Venezuela, and Uruguay in South America, were also combined with the keywords to identify relevant studies. A systematic literature search using the keywords "*oral health-related quality of life*" and "*dental caries*" combined with the names of the different regions and countries listed above was also carried out using the databases mentioned previously. The literature search was completed in August 2020, and the titles, authors, and dates of publication were reviewed to eliminate duplicates.

Eligibility criteria

The eligibility criteria used for the identification of relevant studies have been listed below:

a. National level surveys were prioritized and, when unavailable, the largest and most recent studies were selected;
b. All age groups were included;
c. Studies evaluating dental caries using the World Health Organization (WHO) Criteria were selected;
d. Manuscripts published in Spanish, English, or Portuguese were included.

Publications that met the above criteria were selected for further abstract review, and studies focusing on caries prevalence and DMFT/dmft (Decayed, Missing and Filled Teeth) scores were included. Therefore, the current review excluded studies that did not use the WHO caries criteria.[20] For this method, the stages of caries that precede cavitation as well as other conditions similar to the early stages of caries were not used in these epidemiological surveys. Studies examining special needs or institutionalized participants were not included in this review.[21]

Literature searches were carried out by five researchers focusing on the Central American, Caribbean, and South American regions. Any differences in opinions and doubts with regard to the literature search and study selection process were clarified through discussion between four authors (SP, NA, EI, GT). Although national surveys were prioritized, such evidence was unavailable in some countries and smaller studies examining dental caries was selected in these situations (Figure 1). Table shows the results of dental caries surveys in LACCs, while Figure 2 provides further information on DMFT levels (as per the WHO criteria) among 12 year old population.[21]

Results

Data for Latin American countries

The average DMFT score for 12 year old adolescents in Brazil was 2.1 in 2010,[22] and this was 25% lower than the DMFT score (2.8) observed in 2003.[23] There was a 29% reduction (1.7–1.2) in the untreated (decayed) teeth component, and the proportion of caries-free children (DMFT = 0) increased from 31% in 2003 to 44% in 2010, indicating a significant reduction in the prevalence and severity of caries caused by widespread implementation of preventive measures and improved access to dental restorative services during this period. Additionally, decreasing prevalence of caries and increased access to services was also observed among adolescents (15–19 years old) and adults (35–44 years old), with the average DMFT scores decreasing by 19% from 20.1 in 2003 to 16.8 in 2010.[23] A significant increase of 69% (from 4.2 to 7.3) in the filled teeth component of the DMFT index was also observed, and this was associated with a 50% decrease in the missing teeth component.[22,23]

In Ecuador, national surveys focusing on children and adolescents aged 6, 12, and 15 years were conducted in 1996[24] and 2010,[25] and a reduction in the prevalence of dental caries (from 88.2% to 75.6% of the total sample) was observed in all age groups.[24,25] The Peruvian National Survey of children and adolescents conducted in 2002[26] reported caries prevalence and dmft scores of 87.3% and 6.7, respectively, among 6 year old children. The corresponding scores among 12 year old adolescents were 86.6% and 3.67, respectively.

Figure 1. Representativeness of epidemiological studies in Latin American and Caribbean countries.

The national surveys of children and adolescents in Colombia were performed in 1998 and 2014, and a reduction in the prevalence of caries (from 2.30 to 1.51) was observed among 12 year old adolescents over this time period.[27,28] A similar reduction in caries prevalence was also observed in the same age groups in Chile in 1992 and 2007,[29] and in Paraguay in 1999 and 2008.[30] The 1997 National Survey in Bolivia reported a dmft score of 7.9 among 6 year old children and a DMFT score of 4.7 among 12 year old adolescents, while the most recent national survey conducted in 2015 reported a slight decrease in these scores (dmft: 7.2, DMFT: 4.6).[31] Similarly, Guatemala[32] reported a DMFT score of 4.51 and 6.88 in the 12 and 15 year age groups, respectively.

Although differences in data and study periods were observed between national oral health studies conducted in Argentina (2014),[33] Venezuela (2008)[34] and Uruguay (1992, 2011),[35,36] a comparison of the DMFT scores showed a worrying outcome for Argentina where the DMFT score (3.0) of children aged 12 years in 2014 was similar to that of Uruguay (4.1) in 1992 and higher than that of Venezuela (1.23) in 2008. This highlights the need for prioritizing improvement of oral health conditions in public health policies, particularly in countries with high DMFT/dmft scores.

The first national survey of children and adolescents in Mexico was conducted in 2001[37] and the caries prevalence and dmft scores at the age of 6 were found to be 64.5% and 3.06, respectively. Heterogeneous results were observed in the various states of the country, with the highest scores being observed in the central area of Mexico. The majority of 12 and 15 year old adolescents exhibited dental caries, with prevalence rates being 58% and 68%, respectively. Moreover, approximately two teeth were affected

Table. Descriptive analysis of dental caries in LACC.

Country	Year	Representativeness (type of sample)	Calibration	Index	Sample	D (d)	M (m)	F (f)	DMFT [SD] (dmft)	Prevalence (%)
1.Argentina	2014	National survey	Yes	DMFT	6	–	–	–	–	6 (74,4)
					12				3.0	12 (70.0)
					Total (7785)					
2. Bolivia	2015	National survey	Yes	DMFT (dmft)	6	–	–	–	(7.2)	–
					12				4.6	
3. Brazil	2010	National survey	Yes	DMFT (dmft)	5 (7217)	(2.03)	(0.06)	(0.33)	(2.43)	5 (53.4)
					12 (7247)	1.21	0.12	0.73	2.07	12 (56.5)
					15–19 (5367)	1.7	0.38	2.16	4.25	15–19 (76.1)
					35–44 (9564)	1.94	7.48	7.33	16.75	35–44 (99.1)
					65–74 (7509)	0.62	25.29	1.62	27.53	65–74 (99.8)
					Total (36904)					
4. Chile	2007	National survey	Yes	DMFT (dmft)	6	1.95	1.52	0.24	(3.71)	6 (70.4)
					12	0.75	1.04	0.11	1.9	12 (62.5)
					15				3.0	15 (73.9)
					35–44	–	–	–	15.1	35–44 (99.2)
					65–74				21.6	65–74 (99.4)
5. Colombia	2014	National survey	Yes	DMFT (dmft)	5	–	–	–	(2.82)	5 (52.2)
					12				1.51	12 (37.45)
					15				2.35	15 (44.49)
					20–34				5.98	20–34 (52.81)
					35–44				11.05	35–44 (64.73)
					45–64				15.25	45–64 (61.11)
					65–79				20.55	65–79 (43.47)
					Total (34843)					
6. Costa Rica	1999	National survey	Yes	DMFT (dmft)	6–8 (1260)	–	–	–	–	6–8 (75.2)
					6	(2.15)	(0.46)	(0.77)	(3.38)	6 (70.6)
					7	(1.87)	(0.55)	(1.12)	(3.54)	7 (78.9)
					8	(1.61)	(0.49)	(0.95)	(3.05)	8 (74.1)
					12 (1260)	0.72	0.09	1.65	2.46	12 (71.9)
					15 (1260)	0.96	0.18	3.23	4.37	15 (82.6)
					Total (3780)					
7. Ecuador	2010	National survey	Yes	DMFT (dmft)	6 (700)	(3.62)	(0.08)	(0.92)	(4.62)	6 (79.9)
					12 (822)	0.94	0.11	0.56	1.61	12 (60.8)
					15 (826)	1.57	0.33	1.09	2.99	15 (71.5)
					Total (4358)					
8. Guatemala	2002	National survey	Yes	DMFT	12 (2863)	–	–	–	4.51	–
					15 (1138)				6.88	–
					Total (4001)					
9. Mexico	2014	National Survey*	Yes	DMF (dmft)	6 (18262)	(2.25)	(0.08)	(0.34)	(2.67)	6 (61.29)
					12 (21740)	0.86	0.01	0.24	1.11	12 (46.73)
					15 (15469)	1.28	0.03	0.37	1.68	15 (52.31)
	2019	National Survilance system (SIVEPAB)**			35–44 (45818)	7.05	2.18	3.04	12.27	35–44 (94.26)
					65–74 (15409)	5.78	9.53	2.78	18.04	65–74 (97.94)

Continue

Continuation

Country	Year	Representativeness (type of sample)	Calibration	Index	Sample	D (d)	M (m)	F (f)	DMFT [SD] (dmft)	Prevalence (%)
10. Nicaragua	2002	Leon city survey	Yes	DMFT (dmft)	6	–	–	–	0.11 (3.59)	6 (72.6)
					7				0.13 (3.97)	–
					8				0.36 (3.66)	–
					9				0.60 (2.90)	–
					10				0.82 (0.82)	–
					11				1.00 (1.61)	–
					12				1.51	12 (45.5)
					Total (1400)					
11. Panama	2008	National survey	Yes	DMFT (dmft)	6–12	2.64	0.61	0.16	3.1	6–12 (62.3)
					6–75 (12061)	2.79	5.23	2.16	10.18	6–75 (86.9)
12. Paraguay	2008	National survey	Yes	DMFT (dmft)	6	(5.34)	(0.18)	(0.39)	(5.57)	6 (90.0)
					12	2.24	0.26	0.29	2.79	12 (75.6)
					15	3.29	0.53	0.50	4.34	15 (81.5)
13. Peru	2002	National survey	Yes	DMFT (dmft)	6 (1280)	(6.0)	(0.4)	(0.3)	(6.66)	6 (87.27)
					12 (1291)	3.3	0.2	0.2	3.67	12 (86.64)
					15 (1297)	4.7	0.5	0.7	5.90	15 (91.40)
					Total (7730)	5.10	0.37	0.37	5.84	Total (90.43)
14. Uruguay	1992	National survey	Yes	DMFT (dmft)	6 (1164)	–	–	–	(3.9)	–
					12 (573)				4.1	
	2011	National survey			15–24 (418)				4.1	
					35–44 (229)				15.2	
					65–74 (275)				24.1	
15. Venezuela	2008	National survey	Yes	DMFT (dmft)	6	–	–	–	(2.27)	–
					12				1.23	
					35–44				9.47	
					65–74				21.40	
16. Antigua & Barbuda	2006	National survey	Yes	SiC	6 (485)	(2.31)	(0.10)	(0.04)	(2.45)	253 (52.2)
				DMFT (dmft)	12 (699)	0.76	0.10	0.04	0.90	251 (35.9)
					15 (351)	1.62	0.25	0.05	1.92	126 (53.0)
					Total (1535)					
17. Bahamas	2000	National survey	Yes	DMFT (dmft)	5 (1060)	(2.22)	–	(0.20)	(2.42)	5 (58.0)
					12 (865)	1.30		0.26	1.56	12 (54.5)
					15 (759)	1.62		0.36	1.98	15 (61.0)
					Total (2684)					
18. Cuba	2000	Havana survey	No	DMFT (dmft)	6–7 (82)	–	–	–	0.07	6–7 (6.1)
					8–9 (123)				0.6	8–9 (35.0)
					10–11 (104)				0.8	10–11(40.4)
					12–13 (105)				1.1	12–13 (44.8)
					Total (414)					
19. Dominican Republic	2008	Santo Domingo survey	Yes	DMFT	12–14 (227)	6.0	0.09	1.40	7.49	–
					15–17 (572)	6.78	0.16	1.72	8.66	–
					18–21 (133)	8.38	0.53	1.03	9.94	–
					Total (932)					Total (90.02)

Continue

Continuation

Country	Year	Representativeness (type of sample)	Calibration	Index	Sample	D (d)	M (m)	F (f)	DMFT [SD] (dmft)	Prevalence (%)
20. Grenada	2010	National survey	Yes	DMFT (dmft)	6–8 (652)	1 (9.69)	0 (1.94)	0.03 (0.09)	1.03 (11.72)	–
					14–15 (439)	6.55(0.05)	1.44 (0)	0.41 (0)	8.4 (0.05)	–
					Total (1091)					
21. Haiti	2005	National survey	Yes	DMFS (dmfs)	12 (1260)	0.72	0.09	1.65	2.46	12 (71.9)
					15 (1260)	0.96	0.18	3.23	4.37	15 (82.6)
					Total (2520)					
22. Jamaica	1995	National survey	Yes	DMFT	6				0.22	–
					7				0.47	–
					8				0.41	–
					6–8 (377)	–	–	–	–	6–8 (18.3)
					12 (359)				1.08	12 (41.0)
					15 (377)				3.02	15 (74.53)
					Total (1113)					
23. Martinique	1991	National survey	Yes	DMFT	12 (301)	–	–	–	6.3	12 (75.0)
24. Montserrat	2007	National survey	Yes	DMFT	12 (32)	1.53	0.06	0.31	1.91	12 (59.0)
25. Puerto Rico	2011	National survey	Yes	DMFT	12 (1587)	0.75	0.075	1.675	2.5	12 (69.0)
26. Trinidad & Tobago	2006	National survey	Yes	DMFT	6–8 (788)	2.19	0.28	0.007	2.54	6–8 (72.0)
					12 (488)	0.43	0.07	0.11	0.61	12 (59.0)
					15 (328)	0.67	0.10	0.29	1.06	15 (65.0)
					Total (1604)					

*11 out of 32 states in Mexico included non-cavitated caries lesions. **Ministry of Health, Specific Action Program for the Prevention, Detection and Control of Oral Disease 2019-2024. Preliminary document, August 2020.

by caries (DMFT = 1.91) by the age of 12, and 17.8% of the index score could be attributed to filled teeth. The distribution of DMFT components was similar in the 15 year age group. The second National Mexican Survey was conducted between 2011 and 2014[38] and the results have been presented in Table 1. A decrease in the dmft index (3.06 to 2.67) of primary dentition in children aged 6 years old was observed and, interestingly, the distribution of the components was seen to change. A slight increase in the proportion of filled teeth (from 9.2% to 14.1%) and a noticeable decreased in missing primary teeth (from 25.8% to 2.6%) was seen to occur between 2001 and 2014. In this second survey, 11 out of 32 Mexican states included cavitated and non-cavitated carious lesions in the decayed component of the caries index when examining permanent dentition.[38] Despite this, the caries index scores were found to be lower in the 2014 survey compared to the 2001 survey (1.91 vs 1.11) among children aged 12 years old. This was accompanied by a change in the distribution of the components, with the proportion attributed to the filled component increasing from 17.8% to 28.3%. However, treatment needs remained high, with the largest component of the index formed by untreated carious lesions. Dental caries data for the adult population in Mexico is available from the National Surveillance System,[39] which collects its information from dental surveillance services around the country. In 2019, caries prevalence was higher than 90% among individuals aged 35 years and above, while more than half of the DMFT index score was derived from decayed teeth (57.5%) in the 35–44 years age group. Among patients aged 65–74 years and older, missing teeth formed approximately 52.8% of the DMFT index. Fac-to-face interviews collecting information on edentulism at the national levels found that 25.5% of the 65–74 year age group did not have any natural teeth.[40]

The 2008 National Survey in Panama reported a dmft score of 5.05 among children aged 6 years old, and

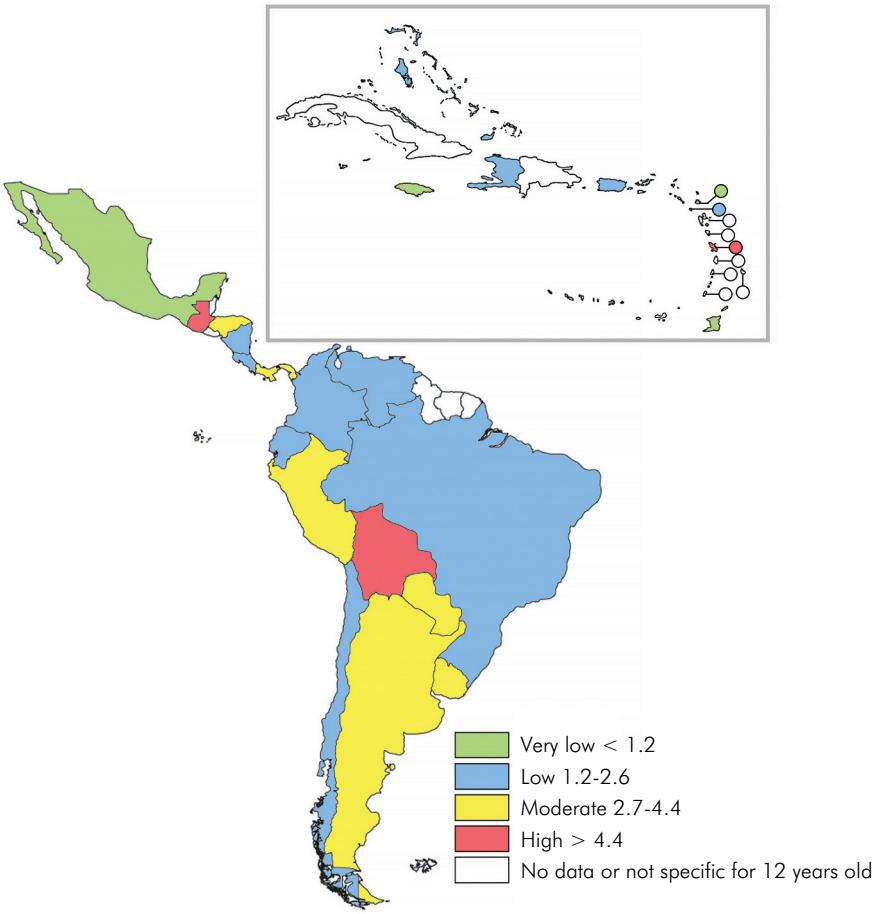

Figure 2. Prevalence of dental caries [DMFT: Decayed, Missing and Filled Teeth index] among children aged 12 years in Latin American and Caribbean countries.

higher values were observed in rural and indigenous communities. The corresponding DMFT scores were 3.97 among children aged 12 years and 10.18 in the whole population (6 to 75 years old). Of this, 27.4% were attributed to decayed teeth and approximately one fifth (21.2%) to filled teeth. The need for prosthetic rehabilitation was high among the adult population.[41] The national survey conducted in El Salvador in 2000 reported dmft scores of 4.0 among children aged 6 years old, and more than 90% of the index could be attributed to the decayed component. This was also true for 12 and 15 year old adolescents, with more than half of the index score being attributed to decayed teeth (Table 1). Data from a dental program conducted in a rural community in 2006 indicated that all children aged 6 years old exhibited dental caries, while a more recent study reported high rates of dental caries among primary teeth and very low prevalence of restored teeth among children in rural communities.[42]

Data on dental caries prevalence in Honduras, is scarce, with a mission dentistry community program conducted in 2017 reporting very high caries index scores in primary teeth (8.7 and 3.7 in children aged 5–6 years and 12 years, respectively).[43] In comparison, a previous study conducted in 1997 reported DMFT scores of 4.51 among children aged 12 years old, suggesting a decrease in caries prevalence over time.[44] A 1999 national survey in Costa Rica reported data for the populations of 6–8, 12, and 15-year-olds. Results indicated a mean dmft of 3.32 for 6–8 year-olds with a dental caries prevalence of 75.2% on the primary dentition. Additionally, the mean DMFT scores of the three age groups were 0.49, 2.46, and 4.37, respectively, while the dental caries prevalence among the 12 and

15 year age groups were 71.9 and 82.6%, respectively.[45] Another national study conducted in 2006 reported a mean DMFT score of 2.57 and caries prevalence of 84.4% among adolescents aged 12 years old.[46] A Nicaraguan study conducted in schools located in the City of Leon followed the methodology proposed by the WHO and reported a mean dmft score of 3.54 and a dental caries prevalence of 77.6% among children aged 6–9 years.[47] Using the same criteria, another study examining children aged 9–12 years reported a mean DMFT score of 0.98 and prevalence rate of 37.9%.[48]

Data for Caribbean countries

The Caribbean region in America is also known as the West Indies and comprises of territories around the Caribbean Sea. Cuba has the largest population and the most extensive territorial dimension in the Caribbean region. In a rural community in the province of La Havana, the DMFT scores of children aged 6–7 years and 12–13 years were 0.07 and 1.1, respectively, in 1997. The prevalence rates for dental caries in the same were 6.1% and 44.8%, respectively.[49] A national study performed in 2005 in Haiti, which has the second largest population in the region, reported a mean DMFT score of 2.46 in the 12 year age group and 4.37 in the 15 year age group. The prevalence of dental caries in these groups were 71.9% and 82.6%, respectively.[50] A previous study reported a DMFT score of 4.4 among children aged 12 years in the Dominican Republic in 1997,[51] while another study conducted in the capital of Santo Domingo reported a mean DMFT score of 7.4 and dental caries prevalence of 90% among 12–14 year old adolescents in 2008.[52] A multi-stage national study conducted in 2011 in Puerto Rico, a territory of the USA, reported a mean DMFT score of 2.5 and dental caries prevalence of 69% among 12 year old adolescents,[53] indicating a reduction in disease prevalence upon comparison to data from another national study conducted in 1997.[54] The 2011 study showed a reduction in the values of the D and M components, and an increase in the values of the F component. A Jamaican national study conducted in 1995 reported mean DMFT scores of 0.22, 1.08, and 3.02 among children aged 6, 12, and 15 years, respectively. The dental caries prevalence in these groups were 18.3%, 41%, and 74.5%, respectively.[55] In Antigua and Barbuda,[56] the dmft score among 6 year old children was 2.45, while the mean dmft scores in the Republic of Trinidad and Tobago were 2.83 among children aged 3–5 years in 2014 and 2.54, 0.61 and 1.06 among the 6–8, 12, and 15 years age groups in 2004, respectively. In 2014, the dental caries prevalence in Trinidad and Tobago was 50.3% in the primary dentition of children aged 3–5 years old, while the corresponding numbers in the 6–8, 12, and 15 year age groups were 72%, 59%, and 65%, respectively.[57,58]

There is very limited epidemiological data on dental caries prevalence in the less populated countries of the Caribbean region. A national study in Martinique reported a mean DMFT score of 6.3 and dental caries prevalence of 75% among 12 year old adolescents in 1991,[59] while another national study conducted in the Bahamas in 2000 reported mean dmft scores of 2.42, 1.56 and 1.98 and dental caries prevalence rates of 58%, 54.5%, and 61% among 5 year old children and 12 and 15 year olds adolescents, respectively.[60] In Grenada, a national study conducted in 2010 reported a mean DMFT and dmft scores of 1.03 and 11.72, respectively, among children aged 6–8 years. This study also reported a mean DMFT score of 8.4 among 14–15 year old adolescents.[61] In Montserrat, a small island in the Caribbean, a national study in 2007 reported a mean DMFT score of 1.91 and a prevalence rate of 59% among adolescents aged 12 years.[62]

Dental caries and OHRQoL

The concept of health has become more comprehensive in recent years, reflecting the complexity of the health-disease process and the need to take both the individual's perception of their health as well as its impact on their quality of life into consideration. The epidemiological evidence of dental caries and its impact on OHRQoL provided in this review aims to further improve the understanding and management of dental caries in LACCs.

Tooth-aches are the most common symptoms of untreated carious lesions and are known to negatively affect the quality of life of individuals, as shown by a Brazilian population-based birth cohort study

examining preschoolers.[63] Another consequence of early childhood caries is its impact on the OHRQoL of children as well as their families, with studies examining Brazilian preschoolers demonstrating that both low and high caries experiences as well disease severity negatively affected the parent's and children's OHRQoL.[64,65,66]

These studies show that oral symptoms and functional limitations can negatively affect the child's OHRQoL by influencing their self-image and social interactions. Furthermore, treatment of dental caries at this stage of life has been shown to cause a significant improvement in the OHRQoL of preschoolers.[67]

In Peru, studies examining preschool children and adolescents showed that the presence of teeth with cavitated decayed dentine with or without pulpal involvement negatively affected the OHRQoL of 3-year-old children from the lower socioeconomic strata of Lima.[68] Moreover, adolescents aged 14–20 years and attending schools in the urban and rural areas of the cities of Lima and Cuzco exhibited a high prevalence of caries, which negatively affected their OHRQoL.[69]

In Ecuador, the impact of dental caries on the OHRQoL was evaluated in adolescents and young adults residing in the city of Quito and the presence of carious lesions along with various socioeconomic factors were found to be associated with poor quality of life in 12 year old adolescents attending public schools.[70] In Colombia, young and mature adults (20–59 years old) with less than 19 teeth, evidence of root remnants and dental calculus in the oral cavity, and the absence of access to health services reported poor OHRQoL.[71] A study in Chile reported compromised quality of life in 37% of individuals aged 15 years and above who exhibited pain, discomfort, and social and functional limitations. Moreover, individuals over 20 years of age were affected more than younger ones due to presentation of more severe symptoms.[72] In Mexico, studies examining children and older adults reported an association between poor OHRQoL and the presence of cavitated carious lesions in children aged 8–13 years. Moreover, participants with International Caries Detection and Assessment System (ICDAS II) ≥ 4 exhibited approximately twice the odds of experiencing a greater negative impact on their OHRQoL compared to children with lower caries experience.[73] Another study examining older adults in Mexico City reported an association between a high number of missing teeth and poor OHRQoL.[74]

In most cases, tooth loss is a consequence of oral disease and its location and distribution may be associated with varying severity of OHRQoL impairment.[75] A 3-year follow-up study among the elderly population of southern Mexico City reported a 5% increase in risk of developing frailty with every additional tooth lost.[76] Data on the dental caries index in El Salvador, Honduras, Panama, and Mexico shows a high prevalence of unmet treatment needs, particularly in primary dentition. Evidence from the Panama National Oral Health Survey showed an increase in the number of missing teeth with aging, with 45.3% of the DMFT index in the 6–75 year old population being attributed to extracted teeth. Moreover, more than half (57.4%) of the adult population also exhibited a need for dental prostheses. Epidemiological data from Panama and El Salvador showed that tooth loss affected urban and rural populations differently, with the latter being more severely affected by dental caries due to limited access to dental services.[41,42]

There is limited evidence on OHRQoL in the Caribbean countries, and currently there are only two studies that have examined this outcome among children and none that focus on adults from this region.[77,78] The first study administered the Early Childhood Oral Health Impact Scale (ECOHIS) to the parents and primary caregivers of children aged 3–5-years and attending preschools in the central region of Caroni in Trinidad and Tobago. The results showed an overall low impact on OHRQoL, the most frequent of which were difficulty in eating and drinking hot or cold beverages; and being irritable or frustrated. Moreover, a negative impact on the OHRQoL was also directly associated with the severity of the lesion, suggesting that untreated carious lesions were associated with poorer OHRQoL.[77] The second study examined the OHRQoL of children aged 6–7-years-old in the Dominican Republic by administering the Scale of Oral Health-Related

Outcomes for 5-Year-Old-Children (SOHO-5) among a low-income sample. The results of this survey showed that 74% of the children faced difficulties with at least one essential life activity, and 58% and 39% of the children reported an inability to eat and drink, respectively.[78]

Recommendations

The recommendations below were based on the present study and paper of Sampaio et al.:[79]

a. Development of new epidemiological studies examining unexplored aspects of the dental caries epidemic in LACCs is essential, and priority should be given to national surveys with samples representative of the population in order to produce high-quality evidence. Such studies should include samples with different age groups, including preschool and school-going children, adolescents, adults, and the elderly population. Standardization of the age groups evaluated will allow comparison of outcomes between countries. Moreover, these surveys should use a well-defined methodology and should include caries detection systems that also consider non-cavitated carious lesions.
b. The countries in the LACC region should collaborate with each other to allow greater access to regional data.
c. National surveys should also receive governmental support as they will provide robust evidence that will inform the development of oral health programs and strategies focused on reducing the dental caries burden in their countries. Public health policies should be based on scientific evidence and should include oral health promotion and dental caries prevention, control, and management measures.
d. Academic institutions should work together to improve oral health and reduce the dental caries prevalence in LACCs.
e. Further evidence on OHRQoL in LACCs is necessary, and inclusion of this component in national surveys is recommended. This type of evidence may help inform public health policies and decisions that aim to improve the OHRQoL of the population, including children, adolescents, adults, and the elderly.
f. Standardized OHRQoL tools with satisfactory psychometric properties should be selected for each age group in LACCs.
g. LACCs should establish alliances with regional and international organizations that support multi-country projects.

Conclusions

A decrease in dental caries prevalence has been observed in several LACCs. This is accompanied by a change in the distribution of the dental caries index (DMFT/dmft), with several countries reporting an increase in the prevalence of filled teeth and a reduction in the number of missing teeth. However, untreated dental carious lesions are still one of the most prevalent conditions among children and adults in this region, with dental caries affecting primary dentition decreasing to a lesser extent than those affecting permanent dentition in most LACCs except Brazil. The majority of surveys reviewed in the current study did not examine the elderly population.

OHRQoL outcomes should be included in all LACC national surveys. Governments should focus on oral health improvement programs for the population as this will not only decrease disease burden but also improve OHRQoL.

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Risk factors for dental caries in Latin American and Caribbean countries

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Abstract: Identifying the risk factors for dental caries is vital in epidemiology and clinical practices for developing effective preventive strategies, both, at the individual and collective levels. Different causality/determination models have been proposed to understand the development process of dental caries. In the present review, we designed a model inspired by the world-known social determinants models proposed in the 90s and more recently in the 10s, wherein the contextual factors are placed more externally and encompass the individual factors. The contextual factors included those related to the cultural and societal values, as well as the social and health government policies. The individual factors were classified into the following categories: socioeconomic (social class, occupation, income, and education level), demographic characteristics (age, sex, and ethnicity), behavioral factors (non-use of fluoride dentifrice, sugar consumption, poor oral hygiene, and lack of preventive dental care), and biological factors (recent caries experience/active caries lesions, biofilm retentive factors, developmental defects of the enamel, disabilities, saliva amount and quality, cariogenic biofilm). Each of these variables was addressed, while focusing on the current evidence from studies conducted in Latin American and Caribbean countries (LACC). Based on the proposed model, educational aspects were addressed, and individual caries risk assessment and management decisions were proposed; further, implications for public health policies and clinical practice were described. The identification of modifiable risk factors for dental caries should be the basis for multi-strategy actions that consider the diversity of Latin American communities.

Keywords: Dental Caries; Risk Factors; Socioeconomic Factors; Health Risk Behaviors; Biology

Introduction

A caries risk factor is defined as a factor/determinant, confirmed by temporal sequence and directly associated with an increased probability of caries.[1] The identification of caries risk factors is important in epidemiology and clinical practice for the development of effective preventive strategies at both, the individual and collective levels.

The theoretical assumption of causality and determination is hereby exposed in a model that describes how risk factors interact to pose a greater

risk for the occurrence of dental caries. Although most factors are well documented in the literature, only description and knowledge of their respective mechanisms of action is insufficient. It is important to discuss the complex interplay among these factors.

Different causality/determination models have been proposed to understand the developmental process of caries. Many of these arise from the authors' theoretical elaborations, scientific literature,[2-5] or statistical and mathematical processes; with the latter, as recently proposed by Foley and Akers[6] who used the causal model based on the Directed Acyclic Graphs that maps the association between variables, creating a causal network. Other models are based on the existing proposals, such as the well-known social determinants model by Dahlgren and Whitehead[7] that employs concentric circles from the most proximal to the most distal factors. Several authors have adapted this model for oral health outcomes[8-11] by changing some variables while maintaining the idea of concentric circles.

In our study, we employed a modified model inspired by different approaches. One approach was the proposal developed by the World Health Organization (WHO)[12] to guide actions focused on the social determinants of health. The social determinants model[7] was also incorporated, recognizing the presence of distal and proximal factors in the determination of dental caries. In this model, the contextual factors are placed more externally, although they encompass the individual factors, not constituting themselves in different dimensions or belonging to the same level of determination. The contextual factors include those related to the cultural and societal values, as well as the social and health policies of the government. The individual factors were classified into the following categories: socioeconomic, demographic, behavioral, and biological factors (Figure 1). Each of these groups was composed of different variables that are discussed later in this article.

Considering the relevance of the consensus papers on caries that was very inclusive within the LACC, we developed the present critical narrative review. An electronic search of the dental literature was conducted in the PubMed, Scopus, LILACS, and SciELO databases, with appropriate keywords and/or phrases; further, a manual search was conducted.

Contextual factors

How are contextual factors usually assessed?

The assessment of the contextual effect on health outcomes is generally performed based on ecological studies, wherein a correlation between the aggregated values at different population levels (cities, states, and countries, in most cases) is analyzed. Since the mid-90s, multilevel models have been used frequently. A limitation of these studies, particularly in the area of oral health, is the poor quality or lack of data on the main problems in oral health, such as dental caries, that are discussed in greater detail in papers 1 and 5 of this LAOHA caries consensus.[13,14] The main repository of WHO-sponsored oral health data, the *Oral Health Country/Area Profile Project* (see at https://capp.mau.se/) maintained by Malmö University presents data from virtually every country in the world. However, these data are quite outdated and have poor accuracy. For some LACC, the most recent information available is > 20 y old, and very few population-based studies are representative of the entire country. However, in spite of these restrictions, the information can be used to assess the global profile of dental caries and the effect of contextual factors.

Databases are more reliable and provide more comprehensive information on socioeconomic variables. Worldwide, numerous researchers have tried to identify the relationship between health and socioeconomic indicators from these databases. In the field of oral health, most of them are based on the comparison of Decayed, Missing, and Filled Teeth (DMFT/dmft) index in different categories of socioeconomic indicators.

Dental caries and contextual factors in LACC

To understand the specificity of the relationship between dental caries and some contextual factors in the 33 countries included in the LACC, we performed an analysis with the data available from the cited sources. Data related to some socioeconomic indicators were gathered from the United Nations Development Programme (UNDP) (http://www.hdr.undp.org/en/data) and the World Bank (https://data.worldbank.org/). Previously collected 12-year DMFT data were

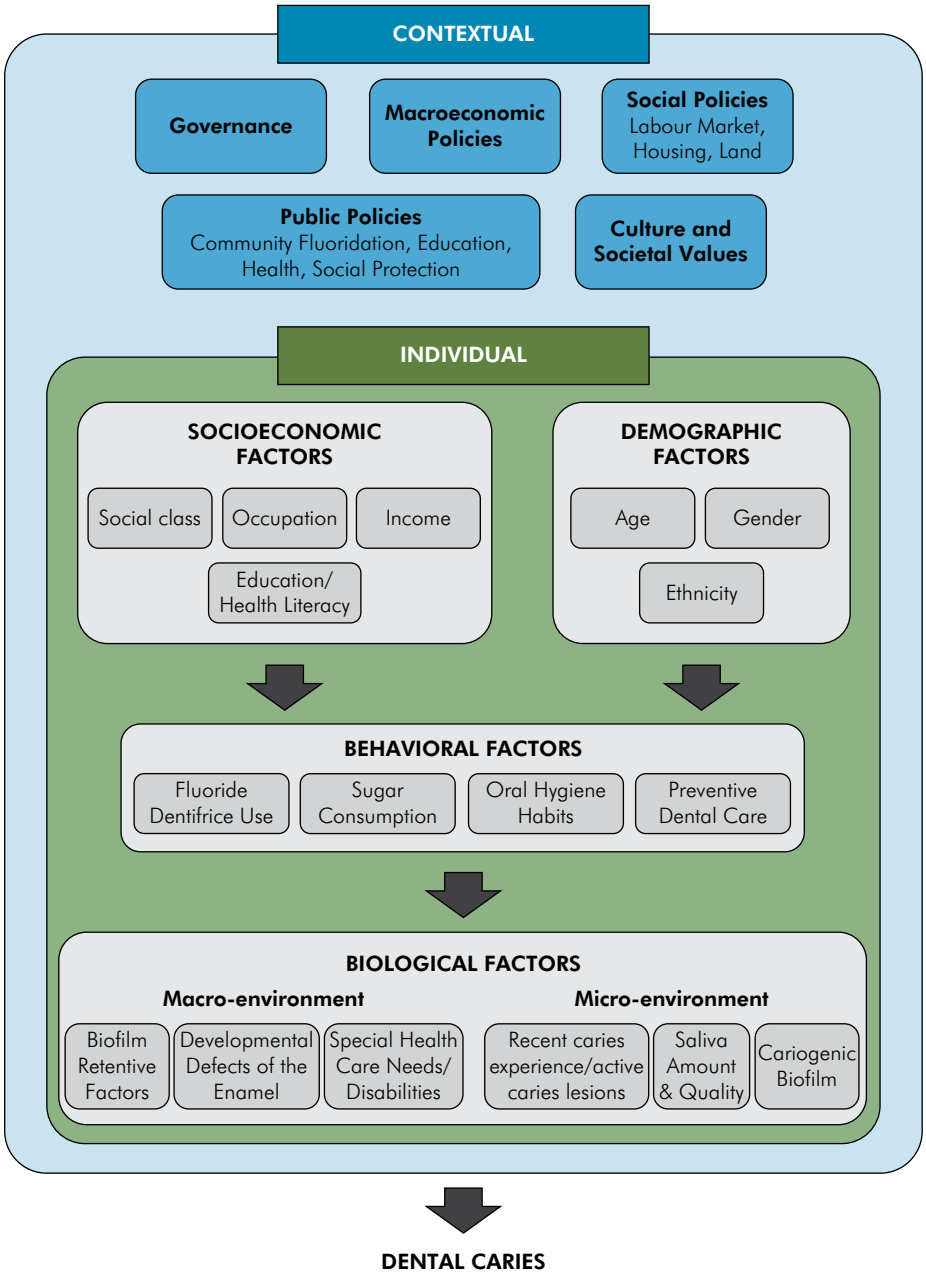
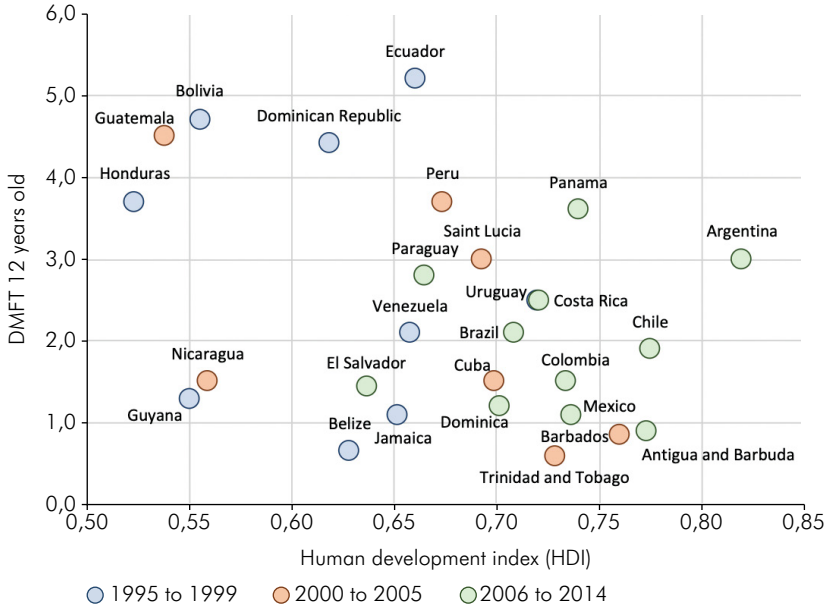


Figure 1. Conceptual framework for the caries risk factors inspired by the WHO Framework[12] and by Dahlgren and Whitehead.[7] Material created by the authors.

obtained from the aforementioned *Oral Health Country/ Area Profile Project* (https://capp.mau.se/). When possible, the database was updated based on a literature search. The reference years in the DMFT database ranged from 1995 to 2014; therefore, we used the socioeconomic data of a year as close as possible. Countries for which data were unavailable for both the variables were excluded from the analysis.

Figure 2 shows the correlation between the DMFT at the age of 12 y and the Human Development Index (HDI), with a weak negative correlation being observed between them; however, the small number of observations rendered no statistical significance and only indicated plausibility.

A similar trend was observed with the Gini index (Figure 3), albeit with a positive relationship; higher



The Human Development Index (HDI) is a statistic composite index of life expectancy, education (Literacy Rate, Gross Enrollment Ratio at different levels and Net Attendance Ratio), and per capita income indicators that are used to rank countries into four tiers of human development. Countries that score higher show greater achievements; Different colors represent the range of years when the data were collected; The circle size is proportional to the population; Pearson correlation only for LACC (r = -0.345; p = 0.078); Source: Prepared by the authors from the data available at the United Nations Development Programme (UNDP) and the Oral Health Country/Area Profile Project.

Figure 2. Correlation between DMFT in 12-year-old children and the Human Development Index (HDI) in LACC. Material created by the authors.

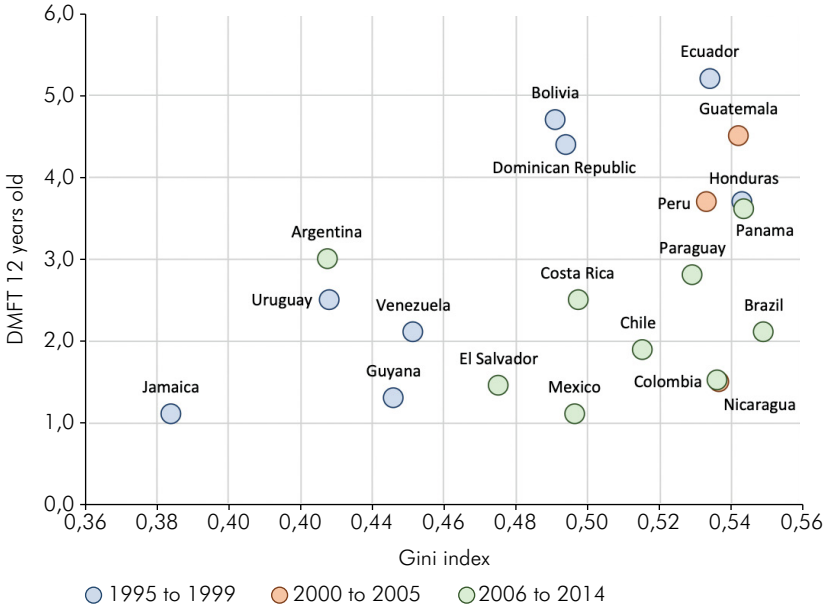
the index, greater the degree of inequality. Countries with lower inequality, such as Uruguay, Jamaica, and Venezuela, and those with greater inequality, such as Ecuador and Guatemala, had lower and higher DMFT values, respectively. This analysis had some limitations, mainly regarding the low extent of the updated data; however, it is important to highlight that this profile was similar to other countries that used more recent information.

As discussed by Roncalli et al.,[15] an association of HDI with DMFT has been observed in Brazil and other countries. Studies using local data, such as the study conducted in Brazil, found a correlation between HDI and oral health outcomes.[16-25] Trials performed in Colombia, Ardila and Agudelo-Suárez[26] showed an association between low HDI and dental pain using a multilevel approach.

The HDI and the Gini index constitute two important aspects of contextual factors because they both represent both a positive characteristic relative to human development index (HDI) and a negative one relative to income inequality, as can be seen in the related Figures 2 and 3 description. This is particularly important because greater indicators of longevity, income, and education are not always associated with greater income distribution; thus, from the viewpoint of the social determination of the disease, these factors have quite different roles.

Bernabé and Hobdell[27] analyzed data from 48 countries and showed an association between the Gini index and previously collected 5 to 6-year dmft values. Only the 22 wealthiest countries were included; therefore, the Gini index presented a significant association, unlike the Gross National Income that showed no association. A significant association between HDI and Gini index was found with a reduction in the incidence of dental caries in Brazilian children when the associated social factors were analyzed.[15]

Another important aspect of contextual factors is the effect of public health and well-being policies. Such analyses are complex, owing to the difficulty of measuring the offered health services. Most studies have analyzed access to health services from an



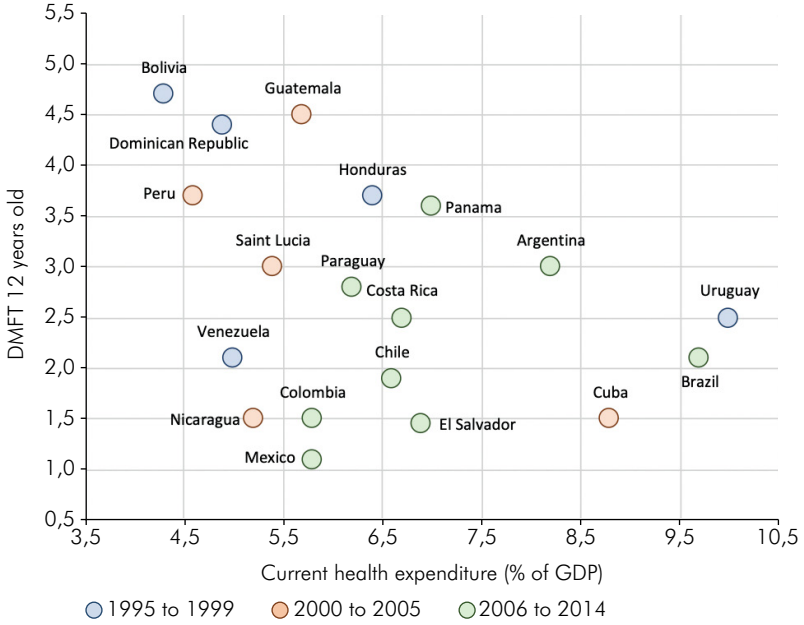
The Gini Index is a measure of statistical dispersion intended to represent the income inequality or wealth inequality within a nation or any other group of people; it measures the inequality among values of a frequency distribution (for example, levels of income). A Gini Index of zero expresses perfect equality, where all values are the same (for example, where everyone has the same income); Different colors represent the range of years when data were collected; Pearson correlation for LACC (r = 0.374; p = 0.103); Source: Prepared by the authors from data available at the World Bank and the Oral Health Country/Area Profile Project.

Figure 3. Correlation between DMFT in 12 years old children and Gini Index in LACC. Material created by the authors.

individual perspective, and in general, based on the use of these services.[22] Guarnizo-Herreño et al.[28] reported the existence of oral health inequalities in adults in all European welfare-state regimes; further, they observed that particular behaviors played a heterogeneous role in explaining these inequalities across the evaluated welfare regimes.[29]

One way of assessing the effect of health policies is to estimate the extent to which countries prioritize health in their public -funding models. Relationships with the workforce, such as the inhabitant/dentist relationship or oral health services coverage is relatively common.[15,19,21,30-33] Most of these studies employ the ecological approach that has intrinsic biases that may interfere with the observation of a genuine effect. One of these biases is attributable to the exposure and outcome being observed at the same time. A given public policy takes a certain amount of time to produce measurable effects, and the best designs to assess them are longitudinal ones or those based on panel data analysis. In any case, ecological studies that aim to evaluate the correlation between the provision of health services and a specific characteristic of the health system, such as financing, are useful because they help generate hypotheses. Figure 4 shows the correlation between these variables. Countries with low investment in health, such as Bolivia, Dominican Republic, and Guatemala, have higher DMFT values. In contrast, countries, such as Argentina, Brazil, Cuba, and Uruguay, that have a higher percentage of investment, have lower DMFT values.

A relevant aspect in this context is the presence of community fluoridation programs. Among these, water fluoridation is the most commonly employed program across the world[34] and is considered the most effective and socially equitable means of achieving community-wide fluoride protection against dental caries.[35] The recommended fluoride water concentration ranges from 0.6 to 1.1 mg/ L,[36] depending on the climate, to achieve a balance between the potential for dental caries reduction and development of dental fluorosis.[35] Water fluoridation programs have an estimated cost of US$ 0.11–4.92/year/capita,[34] and these measures are backed by strong evidence that has demonstrated a



Level of current health expenditure expressed as a percentage of gross domestic product (GDP); estimates of current health; Expenditures include healthcare goods and services consumed during each year; Different colors represent the range of years when data were collected; Pearson correlation for Latin American and Caribbean countries (r =-0.463; p = 0.039); Source: Prepared by the authors from data available at the World Bank and the Oral Health Country/Area Profile Project.

Figure 4. Correlation between DMFT in 12 years old children and current health expenditure (% GDP) in LACC. Material created by the authors.

reduction in the caries prevalence by 26%–35%.[35-36] In contrast, the estimated cost of salt fluoridation is US$ 0.02–0.05/year/capita.[37] The meta-analysis by Yengopal et al. favors it but it states that related available studies are graded as poor-quality.[38] A systematic review[35] suggested that milk fluoridation was beneficial in preventing/reducing caries; however, the quality of evidence was also inferior to that for water fluoridation. The Pan American Health Organization (PAHO) in 1994 launched a multi-year plan to support water and salt fluoridation programs in Central America, South America, and Caribbean countries. It aimed to include more than 400 million people for both the programs by 2010.[39] A table describing the type of community fluoridation and the relevant details in LACC can be found in the "Community interventions and strategies" paper of this LAOHA caries consensus document.[40]

The variable availability of fluoridated toothpaste across countries represents an additional contextual risk factor in Latin America, exposing a large part of the population to an increased risk of dental caries. The legislations of most countries do not ensure that toothpastes have a minimum soluble fluoride concentration so that they exert an anti-caries effect (1,000 ppm of soluble fluoride) mostly because they prioritize the safety of fluoride toothpastes over their anti-caries potential.[41]

Contextual factors are not risk factors per se. They work as modulating elements that must be interpreted as the causes of the causes.[42] In other words, there is no direct way to transport the contextual effects to the individual level. This statement has important implications in the field of dental practice. While it is essential to determine the individual risk factors to guide appropriate interventions, we wish to emphasize that how individuals react to preventive and therapeutic measures depends on the context in which they live. Such reductionism enables an etiological understanding of how ecological exposures affect health; however, it may be counterproductive. In the realm of public health policy and action, contextual factors may serve as the most practical points of intervention in the chain of events.[43,44]

Individual factors

Socioeconomic and demographic factors

This group of caries risk factors comprises social class, occupation, education level, income, sex, age, and ethnicity.

Social class is defined by ownership; it explains how economic inequalities are generated, and how they can influence health.[45] There is a strong association of social and economic conditions with the occurrence of dental caries, indicating that individuals living in low socioeconomic conditions have greater exposure to risk factors that could influence their burden of dental caries.[46,47] A Colombian study demonstrating oral-health inequalities in early childhood found significant associations of caries experience, age, and caregivers' lower educational level.[48]

Occupation is an indicator of the socioeconomic position, determining the individual's place in the societal hierarchy and commonly includes parental occupation as an indicator of a child's socioeconomic position. However, the occupational indicator cannot be assigned to unemployed people; this could underestimate the socioeconomic differences.[45]

Education level is an indicator of the parents' socioeconomic position, determines family income, and is associated with oral health outcomes. Moreover, education provides skills and knowledge that could enable communication; therefore, people become more receptive to oral health information.[49] A systematic review showed that lower parental education was associated with a higher risk of dental caries.[50] In a similar manner, lower maternal educational level was associated with lesser use of dental services, and these children of such mothers with scarce oral health knowledge could have poorer oral health.[51] Oral health literacy has been so far considered in a systematic review as a mediator more than a direct factor for oral conditions, including dental caries.[52]

In addition, income is an indicator of the socioeconomic condition. Family income can be a useful indicator because family expenses are commonly shared by household members.[45] A higher risk of carious lesions has been associated with lower socioeconomic level.[46] In a similar manner, low -income families usually have a diet rich in sugars and fats that in turn led to a higher caries incidence in their children. Family income controls the access to education and oral health services. Therefore, low economic level is associated with scarce preventive care and lowered the prevalence of dental visits.[46]

Sex-based differences have been reported in epidemiological studies with a significant higher prevalence of dental caries in girls than in boys; further, more women use dental health care services.[53,54] A systematic review showed a higher rate of dental caries in Brazilian women.[51] Social and cultural differences between men and women could influence their oral health conditions in different manners.[55]

Race/ethnicity refers to social groups that share ancestry and cultural heritage. It is frequently used for identifying unequal distribution of disease burden, indicating a higher prevalence of dental caries in immigrants or ethnic minorities.[56] Researchers are advised to avoid using race unless the observed differences regarding dental caries cannot be explained by genetics, and the possibility of inadvertently exhibiting racism (individual and structural) should be considered. However, race is not a proxy for racism, but an explanation that should be better studied.[57] However, socioeconomic conditions play an essential role in the association between health and race/ethnicity because oral health problems particularly affect underprivileged people.[45]

Epidemiological surveys have demonstrated an increased prevalence of caries with age, secondary to the cumulative and chronic nature of dental caries. Considerable caries related problems can occur in adults,[58] and older children can have more advance -staged carious lesions than younger children.

Socioeconomic and demographic factors in LACC

In a systematic review,[51] a recent Brazilian population-based study showed that non-white ethnic groups had a higher prevalence of caries in children.[26] Several studies conducted in Latin American indigenous people have shown a rise in the caries prevalence and severity,[45] with a systematic review concluding that sex-based differences and increasing age were associated with a higher caries experience in Guarani and Xavanti groups in Brazil.[59] With respect to the parents' low educational level, an association was

found with higher caries prevalence in cross-sectional studies conducted in Colombia,[60] Mexico,[61] and Chile.[62] Further, low socioeconomic status was associated with a higher prevalence of dental caries.[51,63] A national-level study done in Colombia that looked at the association of different socioeconomic-position dimensions and oral health found that those who lacked national-health insurance and those with lower education levels showed the highest oral health problems.[64]

Cross-sectional studies conducted in Chile in 2–4-year-old and 4-year-old children,[65] as well as in Colombia in 8–71-month-old children,[46] and in Mexico in 3–6-year-old children[61] showed that older age was associated with an increased relevance and severity of caries.

Table 1 shows some studies with respect to the socioeconomic and demographic risk factors and caries in Latin America.

Behavioral risk factors

Behavioral risk factors include dietary practices, mainly high intake of free sugars, lack of oral hygiene, inadequate exposure to fluoride with emphasis on non-use of fluoride toothpaste, and irregular preventive dental care.

Dietary practices

The consumption of free sugars (*i.e.*, sugars added to food and beverages and sugars naturally present in honey, syrups, fruit juices, and fruit juice concentrates) is the key factor that governs the occurrence of caries and modulates other factors, such as the dental biofilm.[73,74] There is evidence that the following two characteristics enhance the role of dietary practices in the trajectory of caries incidence: the age at which sugar is introduced and the frequency of sugar consumption. Cohort studies have shown an association between

Table 1. Investigations regarding socioeconomic and demographic risk factors of dental caries in LACC according to age group.

Author	Study design	Country	Age group	Age (months-m /years-y)	Sample size	Main result
Martignon et al., 2018[48]	Cross-sectional	Anapoima, Colombia	Children	8–71 m	316	Older age and caregivers' low-level education associated with caries.
Zaror et al., 2011[65]	Cross-sectional	Chile		2–4 y	301	Older age associated with caries.
Guizar-Mendoza et al., 2019[61]	Cross-sectional	Bajo León, Mexico		3–6 y	292	Older age and parents' low-level education associated with caries.
Feldens et al., 2010[66]	Cohort	São Leopoldo, Brazil		4 y	340	Mothers' low-level education associated with caries.
Montes et al., 2019[67]	Cross-sectional	Curitiba, Brazil		4–5 y	415	Caregiver's oral health literacy associated with caries.
Herrera et al., 2013[68]	Cross-sectional	Nicaragua		6–9 y	794	Age associated with caries.
Brito et al., 2020[26]	Cross-sectional	São Paulo, Brazil		12 y	26,325	Non-white ethnicity associated with a higher caries prevalence.
Freire et al., 2013[69]	Cross-sectional	Brazil		12 y	7,247	Low income and non-white ethnicity associated with a higher caries prevalence.
Solis-Riggioni et al., 2018[70]	Cross-sectional	Costa Rica	Children and Adolescents	2–17 y	201	Socioeconomic factors associated with caries.
Díaz-Cardenas et al., 2010[60]	Cross-sectional	Cartagena, Colombia		4–13 y	243	Parents' low-level education associated with caries.
Casanova-Rosado et al., 2005[63]	Cross-sectional	Campeche, Mexico		6–13 y	1,806	Low socio-economic status, older age and mother's low-level education level associated with caries.
Echevarria-Lopez et al., 2020[62]	Cross-sectional	Chile	Adolescents and Adults	17–18 y	405	Mother's low-level education associated with caries.
Urzua et al., 2012[71]	Cross-sectional	Cartagena, Colombia	Adults and Elderly	35–44 y 65–74 y	1,088	Age, education level and incomes associated with caries.
Álvarez et al., 2013[72]	Cross-sectional	Uruguay		35–44 y 65–74 y	769	Low socio-economic status was associated with caries.

sugar consumption in the first year of life and the occurrence of dental caries in subsequent years.[75] The early introduction of sucrose in the life of an infant promotes the establishment of a cariogenic microbiota and successive colonization of new dental surfaces. Moreover, early exposure to sugar boosts a child's preference for sweets, resulting in higher consumption of sugar in foods and beverages.[76]

Investigations involving different populations have shown the role of high frequency of sugar intake in the occurrence of caries.[66,74,77,78] There is a dose-dependent response between the ingestion of carbohydrates and dental caries in children and adults; with a greater intake of carbohydrates, especially sugar, increasing the risk of caries. This association is established by the repeated production of acids and the maintenance of a very low pH in the dental biofilm; this is observed in children with high food intake, impeding the physiological replacement of minerals in the de-mineralization/ re-mineralization cycle.

Some studies have examined the effect of two specific dietary practices on the occurrence of caries in children. Breastfeeding lowers child morbidity and mortality and appears to exert a protective effect against the occurrence of caries in the first year of life. However, birth cohort studies controlling for sugar intake have shown a greater risk of caries in infants who breastfeed for > 12 months of life and with a high frequency.[79] Moreover, studies have shown that the use of bottles, especially for sugary beverages at night, was associated with dental caries.[66] Increased risk of caries is related to the sugar content (generally sugar-sweetened beverages) and its accumulation on the biofilm on central incisors that are the most affected teeth in younger children. The cariogenicity of both practices is dependent on the frequency of added sugar consumption. Such sugar is usually offered as a pacifier, mainly at night, when the salivary flow is lower.

In children and adolescents, greater consumption of added sugar increases the risk and occurrence of caries.[74] The risk of caries is lower when the daily consumption of free sugars is reduced to < 10% of the total energy. Moderate evidence shows that the amount and frequency of sugar intake are correlated: children and adolescents who eat sugar frequently tend to consume a large amount of sugar.[80]

Oral hygiene and fluoride toothpaste

Oral hygiene measures aim to remove the dental biofilm, the metabolic activity of which can result in the loss of minerals. Therefore, an increase in the risk of caries in children who do not practice tooth brushing is plausible. However, the quality of the disturbance of the biofilm seems relevant, although a recent systematic review does not show any conclusive evidence on the effectiveness of supervised tooth brushing on caries incidence.[81] Biofilm removal could interact with the diet, as shown in an epidemiological study in children where a higher caries risk was associated with increasing levels of biofilm at all levels of sugar intake, suggesting a synergistic interaction between these two behavioral factors.[82] Furthermore, most people do not remove dental biofilm completely during tooth brushing. Thus, the amount of fluoride retained in the biofilm during tooth brushing is involved in caries control.[83]

Brushing is a simple and cost-effective way of constantly supplying fluoride to the oral cavity.[84,85] However, brushing with a non-fluoridated toothpaste is associated with a higher incidence of caries in children, adolescents, and adults.[81,86] Thus, individuals who combine regular tooth brushing with fluoridated toothpaste have a lower risk of dental caries.[87] There is no clinical evidence of a higher reduction in the risk of caries when the brushing frequency is > 2 times a day,[88] while there is a higher reduction in the risk of caries with increased fluoride concentration in the toothpaste.[87]

A recent critical review conducted in Latin America has shown that one of the most common risk indicators for gingivitis is poor oral hygiene,[89] further highlighting the importance of oral hygiene.

Regular preventive dental care

Regular dental care combines individual behavioral factors with public-policy contextual factors (Figure 1). Absence of regular preventive dental care is associated with a higher number of fillings[90] and poor oral health[47] in adulthood.

The behaviour of attending regularly has been linked to keeping teeth healthy.[91] There is a trend to move toward extended recall intervals and individualized preventive care as per the caries

risk.[92-94] In this context, periodic application of fluoride varnish (or gel) has a substantial caries-inhibiting effect in both, permanent and primary teeth[95,96]. Although not sufficiently established, the interval of dental visits depends on the risk classification of the patient in addition to age. It can vary from 3 months (in higher caries risk) to 12 and 24 months (in lower caries risk) in children and adults, respectively.[92,93,97]

Behavioral factors in populations from Latin America

Studies conducted in Brazil, Chile, and Colombia show that most children in different Latin American communities have access to foods with added sugars in the first two years of life and consume these foods with high frequencies and quantities during early childhood (Table 2). A study involving a representative, multinational sample of adolescents and adults from eight Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, and Venezuela) showed a high frequency of excessive added sugar intake, with minimal differences among the countries.[98] In contrast, the practice of brushing teeth with fluoridated dentifrices has been widespread in Latin American countries since childhood.[99-102] However, some studies have suggested that this habit begins later and occurs less frequently among families with lower socioeconomic status.[103-105]

Table 2 shows some trials on the behavioral risk factors and caries in LACC.

Clinical implications

Knowledge on behavioral caries risk factors suggests that delaying the introduction of sugar in the first years of life; reducing the frequency of consumption throughout life; and exposing children, adolescents, and adults to tooth brushing with a fluoridated toothpaste are potential interventions for reducing the burden of this disease. Excess sugar intake is also a risk factor for cardiovascular disease, diabetes, and obesity;[120,121] therefore, reducing its consumption in individuals should be a goal for all health professionals. The adoption of healthier eating habits does not depend only on behavioral change. Eating practices are also influenced by advertising and food availability at supermarkets and schools. In Latin America, Chile, Peru, Uruguay, and Mexico have nutrient warning policies for reducing sugar intake, recognizing it as a threat to human health.[122]

Biological factors

This group of caries risk factors comprises recent caries experience and active caries lesions, saliva, cariogenic biofilm, plaque stagnation areas, and developmental defects of the enamel.

Both, systematic and narrative reviews have reported that caries experience is the best predictor for the development of caries lesions in the future,[123-129] with moderate to good accuracy in preschool children and limited accuracy in school children/adolescents.[123,124] As a single-risk factor, past or active caries has been classified as strong evidence-based recommendation.[127] Further, the highest caries incidence risk in permanent teeth is seen in the first few years after tooth eruption.[130,131]

Saliva is the most important biological factor involved in the protection against dental caries for several reasons, as follows: a) its buffering capacity restores the dental biofilm pH when the bacteria produce acids; b) salivary flow rate removes the acids from the oral cavity; c) it is supersaturated with calcium and phosphate with respect to the enamel mineral, thus promoting dental re-mineralization under favorable conditions; d) salivary proteins are the main components of the acquired enamel pellicle that acts as a semipermeable barrier, reducing the contact of the acids with the teeth.[132,133] Thus, hyposalivation is related to dental caries.[134] Some systemic and metabolic disorders, such as Sjögren´s syndrome, medications, and head and neck irradiation, may cause salivary hypofunction, increasing the risk of caries.[91,135,136]

The oral microbiota on clinically sound enamel surfaces comprises mainly non-mutans streptococci and *Actinomyces*. In this case, acidification is mild and uncommon, and there is an equilibrium between de- mineralization and re-mineralization or a shift toward re-mineralization. With frequent sugar consumption, there is increased acid formation that changes the composition of the microbiota, increasing acidogenic and aciduric bacteria (*mutans streptococci*,

Table 2. Investigations regarding behavioral factors and dental caries in LACC according to age group.

Author	Study design	Country	Age group	Age (months-m /years-y)	Sample size	Main result
Lopez del Valle et al., 1998[105]	Cross-sectional	Puerto Rico	Children	6–47 m	167	Night bottle, persons, F^- dentifrice & child's age associated with caries.
Hoffmeister et al., 2016[106]	Cross-sectional	Southern Chile		2–4 y	2,987	Sugary drinks high-frequency bedtime consumption associated with caries.
Ribeiro et al., 2017[77]	Cohort	São Luís, Brazil		2–5 y	388	High frequency of sugar consumption associated with caries.
Macias et al., 2016[107]	Cross-sectional	Colombia		24–60 m	546	Dental visits, treatment, oral hygiene, diet & malnutrition associated with caries.
Feldens et al., 2018[78]	Cohort	Porto Alegre, Brazil		3 y	345	High frequency feeding associated with caries.
Percival et al, 2019[108]	Cross-sectional	Trinidad & Tobago		3–5 y	342	Bottle feeding and high plaque levels associated with caries.
Feldens et al., 2010[66]	Cohort	São Leop., Brazil		4 y	340	High density of sugar associated with caries.
Melo et al., 2019[109]	Cohort	Recife, Brazil		5–7 y	469	Consumption of sweets associated with caries.
Ramón-Jimenez et al., 2016[110]	Cross-sectional	Cuba		5–11 y	300	Poor oral hygiene and dental crowding associated with caries.
Herrera et al., 2013[68]	Cross-sectional	Nicaragua		6–9 y	794	Biofilm and toothbrushing associated with caries.
Cipriano-Martinez; Chipana-Herquinio, 2017[111]	Cross-sectional	Perú		6–12 y	129	Poor oral hygiene associated with caries.
García Pérez et al., 2019[112]	Cross-sectional	Mexico, Mexico		8–12 y	522	More sweets per day associated with caries.
Bedos; Brodeur, 2000[113]	Cross-sectional	Haiti		12 y	322	Dental hygiene and sugar intake associated with caries.
Palacios et al., 2016[114]	Cross-sectional	Puerto Rico		12 y	1,587	Carbohydrates, sugars, sucrose, fructose / inositol intake associated with caries.
Fernandez-Vega et al., 2014[115]	Cross-sectional	Venezuela	Children and Adolescents	12–14 y	240	Scarce brushing and rich-carbohydrate foods ingestion associated with caries.
Arrieta-Vargas et al., 2019[116]	Cross-sectional	Guerrero, Mexico	Adolescents	15 y	1,424	Intake of snacks, sweets, and soft drinks associated with caries.
Carmo et al., 2018[117]	Cross-sectional	São Luís, Brazil	Adolescents and Adults	17–18 y	405	Added sugar consumption associated with caries.
Peres et al., 2016[74]	Cohort	Pelotas, Brazil	Adults	18 y	307	The higher the sugar consumption along adolescence, the higher the caries increment.
Rivera-Cruz et al., 2017[118]	Cross-sectional	Cuba	Adolescents, Adults and Elderly	15–69 y	352	Poor oral hygiene and cariogenic diet associated with caries.
Diaz-Sanchez, et al., 2018[119]	Cross-sectional	Cuba	Elderly	Elderly	166	Poor oral hygiene and cariogenic diet associated with caries.

Only studies with samples ≥ 100 participants were included.

lactobacilli, *bifidobacteria*, and yeasts). The net result is the de-mineralization of enamel.[137]

Plaque stagnation areas increase the accumulation of dental biofilm. Consequently, recently erupted first permanent molars are at higher risk of occlusal caries within the first post-eruption year and second permanent molars within the second and third post-eruption years.[124,138,139] This was confirmed in a study performed in Colombian on the first permanent molars of 6-year-old children and the first and second primary molars of 2-year-old children.[139] In particular, Cortes et al.[140] found an increased caries risk on the distal area of the first primary molar when the neighbor primary molar had a concave proximal-surface.

Developmental defects of enamel (DDE) with areas of enamel loss or incomplete mineralization are considered as risk factors for caries related to dental biofilm stagnation.[141] Systematic reviews have shown an association between DDE and caries in the primary[142] and permanent dentition, respectively.[143]

Disabilities caused by a physical or intellectual deficiency, such as cerebral palsy and Down's Syndrome, respectively, may interfere with an individual's routine functions. They may have special needs for assisted tooth brushing, the lack of which can compromise their oral hygiene, increasing their caries risk.[144] Older age is also related to an increased caries risk because of health deterioration and dependence on other people to perform oral hygiene practices.[145]

Table 3 shows some studies conducted in LACC that have reported an association between dental caries and biological factors.

Individual caries risk assessment

Dental caries is a non-communicable disease with a multifactorial etiology that shares risk factors with other highly prevalent non-communicable diseases, such as obesity, diabetes, and cardiovascular disease; sugar intake is one of these risk factors.[97]

The individual caries risk assessment (CRA) is the clinical process of classifying the probability that caries lesions will appear or progress if the conditions remain the same within a defined period.[1,123] It relates to a patient-centered caries management to reduce the risk of caries.[1] CRA is supported in a scientific causal

Table 3. Investigations regarding biological risk factors and caries in LACC according to age group.

Author	Study design	Country	Age group	Age (months-m / years-y)	Sample size	Main result
Cortes et al., 2018[139]	Cohort	Colombia	Children	2–6 y	352	Erupting primary molars and erupting first permanent molars associated with caries.
Cortes et al., 2018[140]	Cohort	Colombia		3–4 y	52	A concave proximal-surface morphology between primary molars associated with a caries lesion in distal of the 1st molar.
Segovia-Villanueva et al., 2006[146]	Cross-sectional	Campeche, Mexico		3–6 y	1,303	Presence of enamel defects associated with caries.
Velasquez et al., 2019[147]	Case-control	Venezuela		6 y	36	Saliva buffering capacity, calcium/ phosphate associated with caries.
Gambetta-Tessini et al., 2019[148]	Cross-sectional	Talca, Chile		6–12 y	577	MIH and HSPM associated with caries and caries severity.
Casanova-Rosado et al., 2005[63]	Cross-sectional	Campeche,		6–13 y	1,806	Enamel defects associated with caries.
Taboada-Aranza et al., 2018[149]	Cross-sectional	Mexico		6–13 y	194	Erupting first permanent molar associated with caries.
Villanueva-Gutierrez et al., 2019[150]	Cross-sectional	Mexico		8–12 y	506	Moderate/severe MIH associated with cavitated carious lesions.
Acevedo et al., 2009[151]	Cross-sectional	Venezuela	Children and Adolescents	2–19 y	48	Biofilm *S. mutans* in caries-affected/free children not associated with caries.
Lopez-Olvera et al., 2018[152]	Cross-sectional	Mexico		3–15 y	42	*S. mutans* in saliva associated with caries.
Cornejo et al., 2008[153]	Cohort	Cordova, Argentina		5–14 y	46	Phosphorus/calcium levels associated with caries.
Santos et al., 2009[154]	Cross-sectional	Brazil	Children, Adolescents and Adults	2–21 y	65	Cerebral palsy associated with caries.
Martinez-Pabón et al., 2013[155]	Cross-sectional	Colombia	Adolescents and Adults	17–34 y	120	Calcium/phosphate concentration and bacteria associated with caries.
Usuga-Vacca et al., 2020[145]	Cross-sectional	Colombia	Elderly	71–89 y	226	Exposed surfaces and coronal caries associated with root caries.

relationship based on risk models, programs, or single predictors validated via prospective cohort studies.[129] The extrapolation of findings from high-quality predictive studies to the dental practice should be performed cautiously.[123]

Although the best indicator of a patient developing caries in the future is previous caries experience,[123,124] the scientific evidence of standardized CRA is still limited;[123,124,129,130] therefore, multivariate risk assessment models are considered optimal for clinical practice because they overcome assessing dental caries risk with only single predictors. These models consider socioeconomic factors, general health, behavior, diet, oral hygiene, and clinical factors including saliva.[97,123,156-158]

CRA is considered a part of the best practices in caries management decision-making, including recall intervals,[91,97,123,159] with desirable effects mostly overweighting the undesirable effects.[160] The multivariate risk models have shown moderate to good accuracy for early childhood caries and lower accuracy for children, adolescents,[123] and adults.[157,158]

Risk assessment models specifically developed for children aged < 6 y include the Dundee Caries Risk Assessment Model (DCRAM) and MySmileBuddy. Those for older children, adolescents, and adults include the Cariogram (also for younger children), the Caries Management by Risk Assessment (CAMBRA), the National University of Singapore model (NUS), the Caries Risk Tool (CAT), PreViser, the Caries Risk Pyramid, the American Dental Association (ADA) caries risk tool, the DCRAM, and the American Association of Pediatric Dentistry model (AAPD).[123,160,161]

More recently, for individuals off all ages, the CariesCare International (CCI), derived from ICCMS, developed a caries risk assessment model by consensus, taking concepts from Cariogram, ADA, and CAMBRA, among others[97] (Figure 5). The CCI individual risk assessment model considers protective factors, social/medical/behavioral risk factors, and clinical risk factors. Protective factors relate to the use of ≥ 1000 ppm fluoridated toothpaste twice a day, dental preventive care, and accessible community fluoride. Social/medical/behavioral risk factors emphasize as the more relevant risk factor the presence of hyposalivation, followed by a high intake of free sugars, while clinical risk factors consider as a key risk factor a recent caries experience and/or the presence of active caries lesions.

CCI considers active caries lesions between smooth, occlusal and proximal tooth surfaces[128] better reflections the metabolic activity in the biofilm.[124] Active carious lesions can be categorized by using the clinical ICDAS-merged severity and activity criteria as follows: based on their severity - initial (ICDAS 1 and 2; non cavitated), -moderate (ICDAS 3 and 4; microcavity and underlying dentine shadow), and - extensive (ICDAS 5 and 6; cavitated), and based on their activity - active when initial/moderate carious lesions present as whitish/yellowish, opaque, rough to gentle probing, in a plaque stagnation area, and as extensive carious lesions when the dentine feels soft or leathery on gentle probing.[97] Figure 6, depicts the ICDAS-merged severity and activity criteria.[97] CCI classifies the patient into the following two risk categories: "lower caries risk" or "higher caries risk," applying a simplified and practical version following a more ethical path,[129] and highlighting clear best-practice management needs, including homecare, clinical approaches, and risk-based intervals (Figure 5).

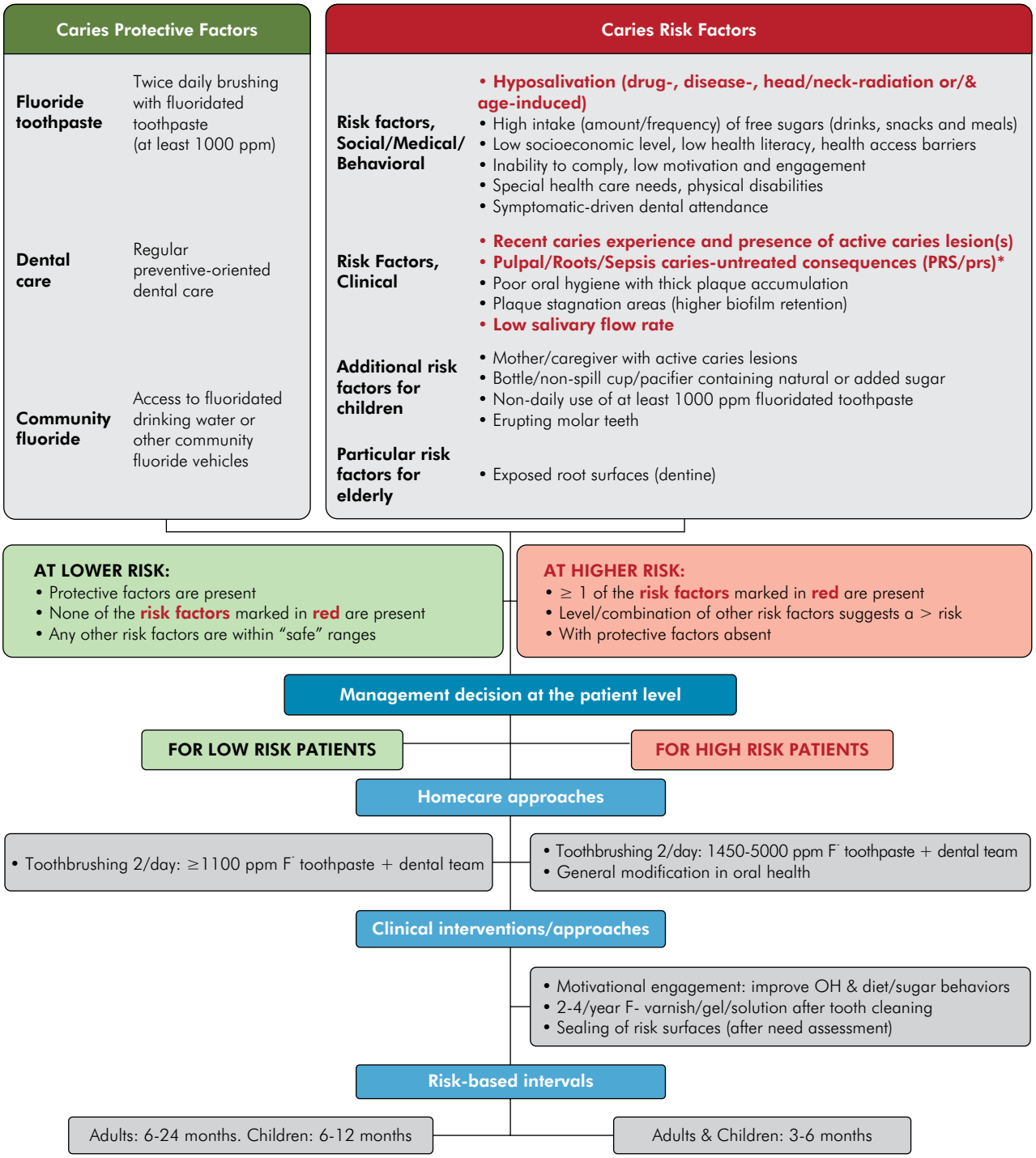
Clinical implications

With regard to ECC, specific protocols focus on the urgency to reduce the risk of dental caries progression, determining the frequency of interventions, and the need to improve primary prevention.[162] In all age groups, high consumption of free sugars should be avoided and brushing teeth twice every day with fluoridated dentifrice of ≥ 1000 ppm F^- should be encouraged.[97]

In the elderly, risk indicators that accurately predict root caries incidence include an increased number of exposed root surfaces and increased root caries experience, gingival recession, poor oral hygiene, and lower socioeconomic level.[146,163,164]

The caries risk status influences the treatment for specific tooth-surface carious lesions in permanent teeth in Colombian dentists, with operative care overruling non-operative care for an initial lesion in the presence of a higher risk of caries.[165]

Age should be considered for the CRA because it is related to individual changes and characteristics at different levels (Figure 3). The caries risk is modifiable



*Pulpal Involvement-Roots-Sepsis Index: clinical consequences of untreated caries. P/p: caries process reached pulp chamber; Roots (R/r): caries process destroyed tooth structures (non-restorable); S/s: pus-releasing tract/tooth-related pus containing swelling.

Material created by the authors.

Figure 5. Individual caries risk assessment, classification, and management decision, adapted from CariesCare International.[90]

by clinical measures and behavioral changes as well as by individual characteristics; therefore, its assessment should be conducted for every patient during the oral health review.[91,97]

		Activity status and signs of ICDAS-merged coronal caries lesions			
		Signs of Likely Active Lesions		Signs of Likely Inactive Lesions	
ICDAS-merged caries stages	Initial (ICDAS 1-2) and Moderate (ICDAS 3-4) Caries Lesions	 Initial  Moderate (Underlying dentine shadow)	• Enamel surface: whitish/yellowish. • Opaque with loss of luster, feels rough to gentle probing across the surface. • Lesion is in a plaque stagnation area. • The lesion may be covered by thick plaque prior to cleaning.	 Initial  Moderate (Microcavity)	• Enamel surface: whitish/brownish/ black. • Enamel may be shiny, feels hard & smooth to gentle probing across the surface. • Smooth surfaces: lesion typically located at some distance from the gingival margin. • Lesion may not be covered by thick plaque prior to cleaning).
	Extensive (ICDAS 5-6) Caries Lesion	 Extensive	• Dentine feels soft or leathery on gentle probing.	 Extensive	• Dentine is shiny and hard on gentle probing.

Material created by the authors.

Figure 6. Activity status and signs of ICDAS-merged coronal caries lesions, adapted from CariesCare International.[96]

Risk assessment and management provides an opportunity to communicate with patients to enable them to adhere and reduce their caries risk, puts oral health into general health, and reinforces the oral health record legally.[97]

Dental educational aspects related to CRA

CRA in the core curriculum of dental students qualifies as a significant competency and is considered an essential component in the decision-making process for correct individual dental caries management. This implies a careful linkage between the teaching and learning processes of caries risk assessment, diagnosis, and synthesis domain, in both, the clinical decision-making and the non-operative and the operative care domains[166]. Evidence-based teaching in dentistry should permeate all aspects of the curriculum. In Spanish-speaking Latin American dental schools, Martignon et al.[167] reported that while 87% dental schools teach caries risk assessment and preventive strategies, only 43% link both of these in the clinic.

In Colombia, after a consensus was achieved in cariology teaching for undergraduate students in 2012 among most dental schools (94%), CRA was designated as a learning objective.[168] This was also the case with the 100% consensus being achieved among 15 dental schools in the Caribbean region, 12 in the Dominican Republic, and 1 each in Puerto Rico, Jamaica, and Trinidad and Tobago.[169] In Brazil, information about caries risk is disseminated via Public health and Integrated seminars, risk factors, and determinants[170] and taught in a theoretical manner in most dental schools (94%).[171] In Chile, all universities teach CRA theoretically,[172] with clinical application being taught at only 40% of all dental schools.[173]

Other data show that students exhibit relatively lower response to the usefulness of a CRA tool, such as Cariogram in the planning of treatments linked to the relatively low knowledge of part-time faculty in using this tool.[174] Calibration training for both, teachers and students may help resolve this issue.[175,176]

General Implications for public health policies

The correct identification of risk factors for dental caries has a direct implication in the implementation of public policies. It allows the organization of oral health services directed at the population that needs it the most. Thus, health policies based on the principles of equity in health care are required. Unfortunately, LACC do not have universal health systems, and

oral health, in turn, is offered in most cases through private health care facilities.

In countries with more consolidated public health systems, oral health policies must use the concept of risk factors beyond the individual level. Ideally, caries risk factors should be embedded in a broader context that includes other preventive strategies in an inter-sectorial perspective. The strategy of common risk factors[42] indicates the need of articulating health education policies for different areas of health. Oral diseases share risk factors with other systemic diseases, such as obesity, diabetes, and cancer; therefore, the adoption of collaborative strategies becomes more rational. In paper 3 of this LAOHA caries consensus, Ricomini-Filho et al. discusses oral public health alternatives in more detail.[40]

General Implications for clinical practice

Considering the available scientific evidence and best practices, caries management at the individual level relates to patient-centered practices wherein risk-based care is highlighted.[93] Despite a low-to-moderate evidence of CRA models and the difficulties in the extrapolation of studies, advantages overcome the disadvantages. There is an agreement for risk assessment, with preference of a multi-factor model over a single factor assessment, involving protective and risk factors, putting oral health into general health, considering the common risk factors' strategy, and leading caries risk management to homecare and in-office approaches with a risk-linked interval recall. More recently, there is a trend to simplify the caries risk classification into the following two categories: higher and lower, to facilitate effective management. The involvement of patients in their oral health care is benefited by the dental team-patient communication through CRA; becoming aware of their disease risk increases the patients' adherence and satisfaction with dental care. In paper 4 of this LAOHA caries consensus, Pozos-Guillén et al.[176] discusses individual caries care alternatives at the tooth level in more detail.

Conclusions and recommendations - Perspectives for LACC

Identifying modifiable risk factors for dental caries should be the basis for multi-strategy actions that consider the historical, ethnic, and cultural diversity of LACC communities.

This includes general measures that address social determinants and specific oral health measures such as:

a. increasing the education level;
b. increasing oral health literacy;
c. reducing poverty and inequality;
d. endorsing community fluoridation policies;
e. supporting upstream measures that promote the reduction of sugar intake, such as policies on advertising, availability, and taxation of sugary products;
f. encouraging healthy dietary practices and discouraging the consumption of free sugars from childhood to adulthood;
g. promoting tooth brushing with ≥ 1000 ppm fluoride-containing toothpaste for all children, adolescents, and adults;
h. promoting patient-centered and risk-based caries care;
i. promoting integrated actions among the dental team and other health care professionals.

Integrated actions among dentists, other health professionals, and policymakers represent the only option for effectively combating the common risk factors to reduce the burden of dental caries and other non-communicable diseases. Moreover, there is a need to conduct higher -quality studies in LACC to achieve a better understanding in our populations regarding the effect of exposures to caries risk factors on dental caries, within the framework of non-communicable disease related to oral health, general health, and quality of life. Peres et al.,[47] highlighted the need for birth cohort studies, epidemiologic and statistical analyses, observational and nested intervention studies, as well as conforming collaborative group studies.

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Original Research
Cariology

Community interventions and strategies for caries control in Latin American and Caribbean countries

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Abstract: Dental caries remains highly prevalent in Latin American and Caribbean countries (LACC). However, this disease can be controlled through interventions that implement evidence-based strategies in an affordable manner and that target all population groups instead of the most affluent only. Therefore, the aim of this report was to summarize the main scientifically documented community interventions and strategies based on restriction of sugars consumption, use of fluoride, and the use of occlusal sealants for caries control in LACC. A critical literature review was carried out in a systematic manner that included defined search strategies, independent review of the identified publications, and compilation of results in this report. Three systematic searches were conducted using the PubMed, LILACS, and SciELO databases to identify studies related to community interventions and strategies for caries control in LACC. Of the 37 publications identified, twenty-six focused on fluoride use, eight on occlusal sealant use, and three on the restriction of sugar consumption. Documented community interventions for sugars restriction were scarce in the region and were based on food supplementation, sugar replacement, and education. Thus, local and/or national policies should prioritize investment in upstream, coherent, and integrated population-wide policies such as taxes on sugary drinks and stronger regulation of advertising and promotion of sugary foods and drinks mainly targeting children. The main fluoride-based strategies used drinking water, refined domestic salt, cow milk, toothpaste and, to a lesser extent, mouth-rinses, acidulated phosphate fluoride (APF) gels, and varnishes to deliver fluoride to the population. Evidence of fluoride use was seen in Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela. Studies reporting the use of occlusal sealants were mainly located in Brazil, Chile, Colombia, Costa Rica, Peru, Mexico, and Venezuela. Community interventions restricting sugar consumption should be implemented at the individual level and through public policies. The use of fluoride must be monitored at the local, regional, and national levels so as to achieve maximum anti-caries effect while also minimizing the risk of dental fluorosis. Moreover, fluoridated water and salt programs, used as a mutually exclusive community level strategy for caries control, should expand their benefits to reach non-covered areas of the LACC

while also simultaneously providing adequate surveillance of the fluoride concentration delivered to the population. Regulating the concentration of soluble fluoride (for anti-caries effect) in dentifrice formulations is also necessary in order to provide the population with an effective strategy for disease control. Targeting culturally appropriate, economically sustainable caries control interventions to rural populations and native ethnic groups such as indigenous people, quilombolas (African-origin), and riverside Amazonian people remains a crucial challenge.

Keywords: Dental Caries; Latin American; Caribbean Region; Sugars; Fluorides.

Introduction

Despite rapid advances in the understanding of dental caries and strategies to control it,[1] the disease continues to be highly prevalent in many countries, particularly in Latin American and Caribbean countries (LACC).[2,3] Dental caries occurs due to frequent exposure of the dental biofilm to sugars, highlighting the key role that dietary carbohydrates play in disease onset and progression.[4,5] These sugars are fermented by bacteria present in the biofilm, producing acids that lead to tooth (enamel/dentine) demineralization via a physicochemical process.[6] Consequently, teeth that are exposed to periods of demineralization more frequently than remineralization, which is a naturally occurring process, exhibit increased loss of tooth minerals and subsequent development of caries lesions.[4]

Sugars play a pivotal role in the development of dental caries as without fermentable carbohydrates, the bacteria are unable to produce acids necessary for tooth demineralization.[4] This suggests that the disease can be controlled, and various community and population-based intervention strategies have been applied to interfere with the de-remineralization process contributing to reduce mineral loss. Methods to control caries based on the restriction of sugar consumption, use of fluoride, and placement of occlusal sealants have been implemented. The strategy based on restriction of sugar consumption aims not only to reduce the consumption, but also focuses on the use of alternative sweetening compounds that are not fermented by bacteria as well as substances with putative anti-caries activity.

Another well-established strategy for caries control involves the use of fluoride which interfere with the physicochemical process of tooth (enamel/dentine) mineral dissolution.[7] The presence of fluoride in the oral cavity not only reduces demineralization but also enhances tooth re-mineralization.[8] Intervention strategies typically rely on different approaches to deliver fluoride into the oral cavity, and these can be classified into different categories based on their level of action, as follows: community level (water, salt, and milk fluoridation), individual level (fluoride dentifrices and mouthrinses), and clinical interventions (gel, varnish, foam). From the public health perspective, individual actions that are not isolated but are a part of a general systematic effort aiming to produce an effect in the population are considered to be actions at the community level. These include school programs incorporating the use of fluoridated mouthwashes and supervised tooth-brushing with fluoridated toothpastes. Irrespective of the approach employed, the common goal of all of these interventions is to maintain a certain concentration of fluoride in the oral cavity so as to enhance its preventive and therapeutic effects.

When used within the framework of a community program, the placement of dental sealants to cover pits and fissures on the occlusal surfaces of teeth has also been found to be effective in controlling caries, particularly in high-risk individuals.[9] The fissured occlusal surfaces of first permanent molars as well as their lower buccal and upper lingual pits are highly susceptible to caries lesions, and the use of occlusal sealants in these areas not only prevents the onset of caries lesions by interfering with bacterial adhesion and growth but also acts as a physical barrier and helps to seal dental irregularities, thus protecting the tooth surfaces from interaction with bacterial acids responsible for demineralization. There are a wide

range of commercially available occlusal sealant materials, the most common of which are resins and glass-ionomer based cements.

Although such community interventions and strategies have been adopted for caries control, compiled data on their use in Latin American and Caribbean countries (LACC) or summarized evidence on their effectiveness are scarce. Further exploration of the extent of implementation of these measures in LACC will not only help develop a better understanding of the actual scenario in these countries, but also guide public health policies and decision-making with regard to the appropriateness of community and individual-level interventions for caries control within the context of these regions. Therefore, the aim of this report was to summarize the main scientifically documented community interventions and strategies based on restriction of sugar consumption, use of fluoride, and the use of occlusal sealants for caries control in LACC.

Methodology

Search method and inclusion/exclusion criteria

Three separate systematic searches were carried out to identify studies related to community interventions and strategies aiming to control caries in LACC by a) restricting sugar consumption, b) using fluoride, and c) placement of dental sealants. Prior to this, the researchers were calibrated by carrying out a pilot search aiming to identify studies focusing on restriction of sugar exposure and use of fluoride using the database, PubMed.

The search string used for identifying interventions restricting sugars consumption for caries control in LACC was as follows: [Sugar OR Sugars OR Dietary Sugars OR Dietary Sucrose OR High Fructose Corn Syrup OR Disaccharides OR Lactose OR Monosaccharides OR Sugar Sweetened Beverages OR Sugar-Added Beverages OR Sweetened Drinks OR Sugar-Sweetened Soft Drinks OR Sugar Sweetened Soft Drinks OR Sugar-Sweetened Sodas OR Candies OR Caramel Candy OR Sugar (MeSH terms) OR Sugar-Sweetened beverages (MeSH terms) OR Candy (MeSH terms)] AND (Dental caries) AND (strategy OR program OR policy OR prevention OR protection OR regulation OR control OR restriction OR effective).

The search string used for identifying interventions using fluoride for caries control in LACC was as follows: [Fluoride OR Fluoridated toothpaste OR Fluoridated dentifrice OR Fluoridated varnish OR Fluoridated water OR Acidulated Fluoride Phosphate OR Topical Fluorides OR Fluoride Varnishes OR Fluoride gels OR Fluoridated gels OR Fluoride foams OR fluoridated foams OR Silver diamine fluoride OR Milk Fluoridation OR Water Fluoridation OR Fluoridation OR Salt Fluoridation OR Fluorides (MeSH terms) OR Sodium fluoride (MeSH terms) OR Acidulated Phosphate Fluoride (MeSH terms)] AND (strategy OR program OR policy OR prevention OR protection OR regulation) AND (coverage OR effective OR extent) NOT (Rats OR Mice OR "In Vitro" OR "In Situ" OR Cell OR Bovine). Additionally, LACC names were also included as a search term to increase accuracy.

These pilot searches recovered 239 studies on sugars restriction and 561 studies on fluoride use via community interventions and strategies for caries control. The Rayyan web-tool was used during the selection/exclusion process,[10] and a total of 100 studies from each topic were selected to be independently evaluated by two reviewers (sugars restriction: B.A.C. and R.A.G.; fluoride use: A.P.R.F. and P.F.). The titles and abstracts were screened for eligibility, and the selection criteria were established during this stage. Studies reporting strategies based on the restriction of sugar consumption or fluoride use for caries control in at least one Latin American and Caribbean country were included, while those that were of the wrong publication type, did not address the research question, or did not have an abstract available were excluded.

Thereafter, final searches for studies on interventions restricting sugar consumption and fluoride (June 17, 2020) use were carried out on the PubMed, LILACS, and SciELO databases using the same keywords with minor modifications relevant to each database. A third systematic search to identify strategies based on the use of pit and fissure sealants for caries control (July 28, 2020) was also carried out on PubMed using the following search string: (Sealants

OR Pit Fissure Sealants OR Dental Sealants OR Tooth Sealants OR Fissure Sealants) AND (strategy OR program OR policy OR prevention OR protection OR regulation) AND (coverage OR effective OR extent) AND (Belize OR Costa Rica OR El Salvador OR Guatemala OR Honduras OR Mexico OR Nicaragua OR Panama OR Argentina OR Bolivia OR Brazil OR Chile OR Colombia OR Ecuador OR French Guiana OR Guyana OR Paraguay OR Peru OR Suriname OR Uruguay OR Venezuela OR Cuba OR Dominican Republic OR Haiti OR Guadeloupe OR Martinique OR Puerto Rico OR Saint-Barthélemy OR Saint-Martin) NOT (Rats OR Mice OR "In Vitro" OR "In Situ" OR Cell OR Bovine). The same search strings were used on the LILACS and SciELO databases with minor relevant modifications.

The studies recovered from these searches were then uploaded in to the Rayyan web-tool and organized into the three relevant categories. Duplicated studies were identified and removed, and each topic was independently evaluated by two reviewers (sugar restriction: B.A.C. and R.A.G.; fluoride use: A.P.R.F. and P.F.; and dental sealant: A.P.R.F. and P.F.). The titles and abstracts were screened for eligibility. Studies focusing on the restriction of sugar consumption were categorized based on the intervention strategy, as follows: education, sugar replacement, and food supplementation. Studies focusing on fluoride use were categorized based on the method of delivery used, as follows: water, salt, milk, dentifrice, acidulated phosphate fluoride (APF) gel, mouth-rinse, and varnish. Lastly, studies focusing on the use of dental sealants were evaluated as a single topic without further categorization. The studies within the three topics were also organized according to LACC, and the current report is structured to provide data on at least one representative study from each LACC identified as using restriction of sugar consumption, fluoride use, or dental sealant as a strategy for caries control. The search strategy and study selection methods have been summarized in Figure.

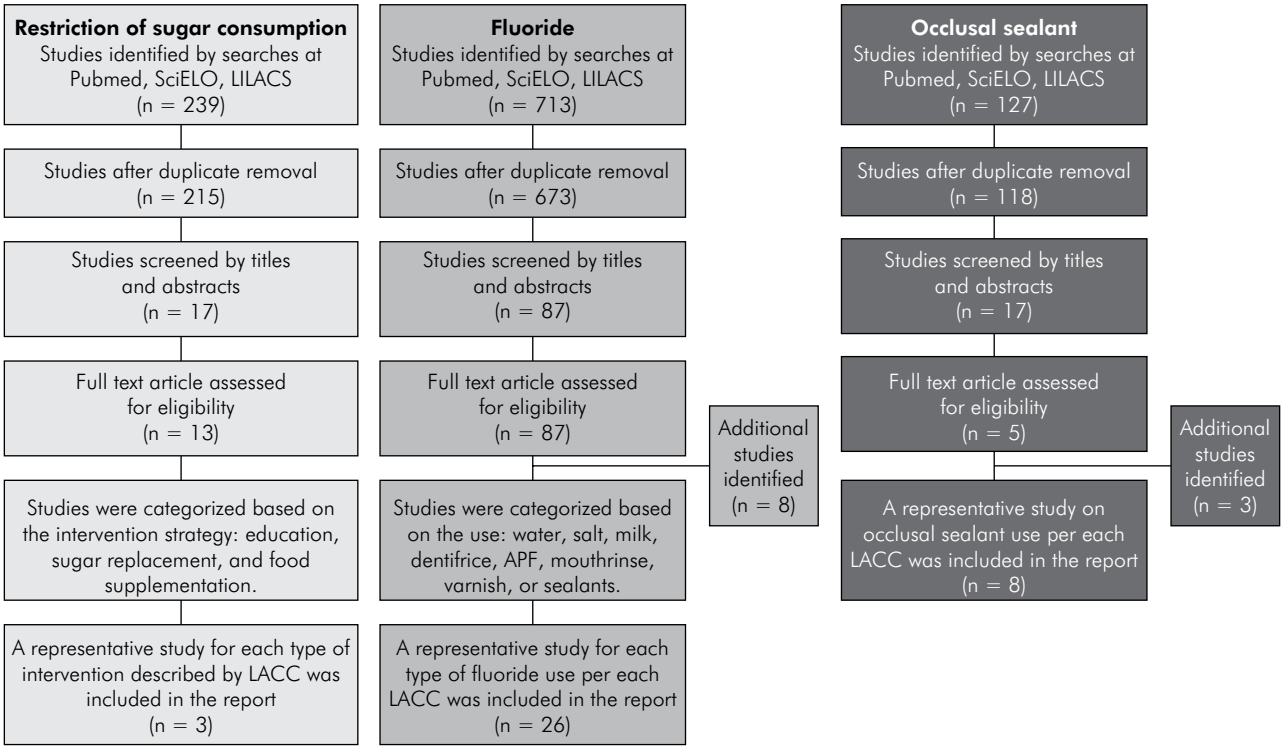

Figure. Summary of systematic search method for identification of interventions based on restriction of sugar consumption, fluoride use, and placement of occlusal sealants for caries control in Latin American and Caribbean countries (LACC).

Results

The identified studies focusing on interventions using restriction of sugar consumption, fluoride use, or dental sealant as a strategy for caries control in LACC are shown in Tables 1, 2 and 3, respectively. The search method (Figure) yielded the highest number of studies focusing on interventions based on fluoride use (Table 2), followed by a smaller number of studies focusing on restriction of sugar consumption (Table 1) and use of occlusal sealants (Table 3) for caries control.

Several LACC such as Belize, Brazil, Chile, Colombia, Puerto Rico, and Venezuela adopted interventions based on restricted exposure to sugar via food supplementation, sugar replacement, and education. Two studies (one of which was a pilot study) reported interventions aimed at food supplementation using probiotics, while another focused on a school-based intervention[11] that showed a significant reduction in caries upon administration of milk twice per day among preschool children. The most common methods of sugar replacement for caries control involved the use of chewing gums (reported by 6 out of 7 relevant studies) and sorbitol mints (reported by one study), and the majority of studies reported adopting a polyol-based approach to replacing sucrose. Four of the screened publications reported findings from a single study and its follow-up carried out in Belize,[12] and their results suggested

Table 1. Interventions based on restriction of sugar consumption for dental caries control in Latin American and Caribbean countries (LACCs).

LACC	Author	Intervention	Summarized findings
Chile	Rodríguez et al., 2016[11]	Food supplementation	**Aim:** To determine the effects of probiotic-milk supplementation on caries incidence in preschool children. **Methodology:** Triple-blinded, placebo-controlled randomized trial; 261 children aged 2 - 3 years old from 16 nursery schools in Santiago, Chile were included. The nursery schools were allocated into two arms, as follows: 1) Intervention arm: 150 mL of milk supplemented with *Lactobacillus rhamnosus* SP1 (10^7 CFU/mL) administered on weekdays for 10 months, and 2) Control arm: non-supplemented cow milk administered. Follow-up lasted 10 months with a clinical exam at the end. Dropout rate: 21%. **Outcomes**: Caries increment using ICDAS. **Results**: The probiotic (intervention) group showed a lower caries prevalence (54.4%) compared to the control group (65.8%). Caries incidence (cavitated lesions; ICDAS 5-6) in the intervention group was significantly lower (9.7%) compared to the control group (24.3%), with OR= 0.35 ($p < 0.05$).
Belize	Makinen et al., 1995[12]	Sugar replacement	**Aim:** To determine the cariogenicity of sucrose-based chewing gums in children. **Methodology:** Double-blinded cohort study; 1277 children (mean age: 10.2 years) included. Nine study arms: 1) Control (no gum); 2), 3), 4) and 5): Xylitol used in different amounts (range: 4.3–9.0 g/day); 6) and 7): Xylitol/Sorbitol (range of polyols: 8.0–9.7 g/day); 8): Sorbitol (9.0 g/day); and 9) Sucrose (9.0 g/day). Gum use was supervised and the program was implemented for 40 months. **Outcome:** Modified WHO procedure for identification of non-cavitated and cavitated carious lesions. **Results:** Sucrose gums increased the caries scores (RR 1.20; CI 0.96 - 1.49; $p = 0.1128$), while sorbitol gums decreased the caries scores (RR 0.74; CI 0.6 - 0.92; $p = 0.0074$). Although all four variants of Xylitol gums were effective in decreasing caries rates, the most effective were those containing 100% Xylitol (RR 0.27; CI 0.20 - 0.36; $p = 0.0001$). The Xylitol/Sorbitol combination decreased caries incidence compared to the control group, but was less effective than the Xylitol only group.
Brazil	Feldens et al, 2007[13]	Education	**Aim:** To determine the effectiveness of home visits to educate mothers on the effects of breast feeding and weaning on early childhood caries (ECC). **Methodology:** Randomized community trial including 500 mother-child pairs (intervention group: 200, control group: 300). Intervention: Advice 10 days after the child's birth, repeated monthly up to 6 months, and then again at 8, 10, and 12 months. **Outcomes:** Early childhood caries at 12 months (decayed surfaces). **Results:** Intervention group: 10.2% with ECC; Control group: 18.3% with ECC. The intervention group had 48% lower odds of developing caries (OR 0.52, CI 0.27 - 0.97) compared to the control group. Mean DS was lower for the intervention group (0.37) than the control group (0.63). The intervention group also exhibited longer duration of exclusive breast feeding, later introduction of sugar to the diet, and lower probability of eating sugary foods.

Table 2. Fluoride use for dental caries control in Latin American and Caribbean countries (LACCs).

LACC	Author	Fluoride use	Summarized findings
Argentina*	Durán et al., 2017[14]	Water	1975 - Law proposing fluoridation or de-fluoridation of drinking water to achieve optimal fluoride concentration passed. Samples of water (2008 - 2012) were collected from 190 localities in 17 departments in the province of Tucumán, Argentina. The results showed that 1% of the population consumed water with optimal fluoride concentration (0.7–1.0 ppm F), 94% consumed water with fluoride concentrations below the recommended limits, and 5% were exposed to fluoride concentrations above the optimal limit
Brazil	Roncalli et al., 2019[15]		1974 - Brazilian legislation on fluoridation of water supply passed. Data on the fluoridation process and the concentration of fluoride in the public water supply in all 614 municipalities of Brazil (>50,000 inhabitants representing 65% of the Brazilian population) evaluated in 2012. The proportions of municipalities without access to fluoridated water were as follows: North (88.9%), North-east (52.3%), Mid-west (22.9%), South-east (10.8%), and South (2%). The remaining proportions represented municipalities that had access to water fluoridation in whole or in part. The sanitation strategies adopted in larger cities serve as a basis for smaller demographic municipalities in the same regions by the influence they have.
Cuba	Künzel and Fischer, 2000[16]		1973 - Water fluoridation program was implemented. Pilot fluoridation plant was installed in the rural community of La Salud, Province of Habana. 1990 - Cuba stopped the import of fluoride due to economic problems.
Chile	Yévenes et al., 2019[17]	Water and milk	Water fluoridation was first implemented in some cities in 1953, and was then expanded to other cities in the country by 1984. In rural areas with no access to tap water, fluoride was provided though a Fluoridated School Feeding Program using milk. Currently, 83 % of the urban population, representing 72% of the total population of Chile, has access to fluoridated drinking water.
Brazil	Cury et al., 2004[18]	Water, dentifrices, APF, and mouth-rinses	1953 - Water fluoridation introduced; 1975 - federal law advising water fluoridation in all cities having water treatment systems passed. 1989 - The most popular commercially available Brazilian dentifrice was fluoridated. 1990s - Spread of preventive programs (tooth-brushing at schools with fluoride dentifrices, weekly fluoride rinsing, and APF application). 1990s - 90% of commercially available dentifrices fluoridated. Water fluoridation, expansion of preventive programs at schools, and the widespread use of fluoride dentifrices are consistently linked to the decline in caries incidence observed in Brazil (1986–2003).
Haiti	Bedos and Brodeur, 2000[19]	Water and sealant	Although caries prevention methods such as the application of occlusal sealants and the use of fluoridated water have been mentioned as desirable, the associated costs make implementation difficult for a developing country.
Belize, Bolivia, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Mexico, Peru, Uruguay, and Venezuela	Marthaler, 2013[20]	Salt	Salt fluoridation programs - Colombia, Costa Rica, Mexico, and Uruguay have over 20 years of documented use of fluoridated salt provided to 160 million people. Belize, Bolivia, Cuba, Dominican Republic, Ecuador, Peru, Venezuela have also implemented salt fluoridation programs.
Mexico	Betancourt-Lineares et al., 2013[21]		1988 - National Salt Fluoridation Program (PNFS) implemented in Mexico. Five states excluded due to the presence of natural fluoride in higher than optimal concentration in the water. Partially incorporated in eleven states due to the presence of natural fluoride in concentrations > 0.7 ppm in the water supply of some municipalities. Concerns about dental fluorosis.
	García-Pérez et al., 2013[22]		Two rural towns in Mexico with natural fluoride concentrations of 0.7 to 1.5 ppm in the water also receive fluoridated salt. Higher fluorosis levels were observed in the town with higher concentration of fluoride in water (1.0 ppm). A difference in the prevalence of caries among children living in the two towns was observed.

Continue

Continuation

LACC	Author	Fluoride use	Summarized findings
Venezuela	Montero et al., 2007[23]	Salt	1995 - Salt fluoridation program implemented. The main sources of fluoride exposure: dentifrices (1100 mgF/L), salt (60–90 mgF/L), and naturally fluoridated water with concentrations ranging from 0.13 to 2.32 mgF/L. Two types of salts available: a) fluoridated, to be consumed in areas with concentrations of fluoride < 0.5 mg/L in drinking water, and b) non-fluoridated, to be distributed in areas with high prevalence of dental fluorosis. The consumption of fluoridated salt in areas with high rates of dental fluorosis only increased the risk further.
Nicaragua	Walsh and Cury, 2018[24]		2007 - Law mandating fluoridation of salt (concentration range: 200–225 mg/kg) for human consumption passed in Nicaragua. Fluoride concentration in 11 brands of salt sold in Managua, Nicaragua evaluated. Of these, only two brands presented optimal fluoride concentration, as required by the legislation. Among the other brands, 2 were not fluoridated and five had fluoride concentrations below the mandated range. Surveillance systems for the salt fluoridation program should be improved.
Peru	Cury et al., 2018[25]		Peruvian legislation states that salt for human consumption should be fluoridated (concentration range: 200–250 mg F/kg). Fluoride concentration in four brands of salt commercially available in Lima, Peru were evaluated. The fluoride concentrations were not homogeneous in any of the salt samples (ranging from 72.0 to 1449.7 mg F/kg). The manufacturing and sanitary surveillance of fluoride salt in Peru should be improved.
Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela	Gillespie and Baez, 2005[26]	Salt and water	1964 - 1972 - Colombia Trial for use of fluoridated salt - The clinical results showed changes in dental caries prevalence, and the efficacy of fluoridated salt was comparable to that of water fluoridation. 1972 - 1986 - Discussion to implement salt fluoridation in Latin American and Caribbean countries. Colombia was committed to fluoridated salt. Brazil, Chile, and Argentina were interested in expanding water fluoridation. 1986 - 1992 - Costa Rica, Uruguay, Peru, and Mexico (areas with low fluoride) implemented fluoridated salt programs. Since Nicaragua and El Salvador already had natural fluoride in their water supply, the need for additional fluoride sources had to be evaluated. 1992 - 2004 - Honduras, Guatemala, Paraguay, and Nicaragua implemented fluoridated salt programs. Argentina commenced production of fluoridated salt. Venezuela, Bolivia, Cuba, Dominican Republic, and Ecuador began initiating programs. Most countries in Latin America, with the exceptions of Brazil, Chile, and Panama, had implemented use of fluoridated salt.
Brazil, and Uruguay	Fabruccin et al., 2016[27]		Two population-based oral health surveys of 12-year-old school children exposed to a) artificially fluoridated water in Porto Alegre, South Brazil, and b) artificially fluoridated salt in Montevideo, Uruguay. "Salt fluoridation is recommended by the WHO as an alternative method when water fluoridation might be unavailable for technical, financial, or sociocultural reasons." Furthermore, the salt fluoridation program in Uruguay is limited to salt for domestic use only, with no coverage of public and private canteens, restaurants, and bakeries as recommended by the WHO. In Porto Alegre, most of the water for human consumption, available through the public water supply system or as commercially available bottles, is fluoridated.
Cuba	García Melián et al., 2002[28]		2001 - Cuba implemented a salt fluoridation program. However, areas with natural fluoride present in the water supply do not receive fluoridated salt and are also monitored to ensure optimal levels of fluoride concentration for caries control.
Colombia	Agudelo-Suárez et al., 2013[29]	Salt, water, and milk	The use of fluoride as a public health strategy may be hindered by the prevalence and severity of dental fluorosis. This is further complicated by a general lack of knowledge regarding dental fluorosis (even by health professionals) and the absence of monitoring to ensure appropriate fluoride use. This is a common concern in most Latin American countries with salt and water fluoridation programs; however, the occurrence of high concentrations of fluoride in the water in some regions may result in dental fluorosis, as seen in some parts of Mexico. From a public health perspective, policies and strategies should attempt to eliminate or reduce simultaneous sources of systemic fluoridation (water, salt, or other supplements).

Continue

Continuation

LACC	Author	Fluoride use	Summarized findings
Peru	Vallejos-Ragas and Tineo-Tueros, 2015[30]	Salt, mouth-rinse, APF, milk, and dentifrices	1964 - 2% sodium fluoride solution applied on the tooth surfaces. Four applications at different time points in the child's life (3, 7, 10, and 13-years-old). 1984 - Salt fluoridation program implemented. 1985 to 2008 - 0.2% sodium fluoride mouth-rinse administered to children in public schools. 1995 to 2000 - 1.23% acidulated phosphate fluoride (APF) gels used to complement the mouth-rinse program. 1999 - 2004 - Milk fluoridation program 2001 - Regulations regarding the addition of fluoride to dentifrices and mouth-rinses published.
Brazil	Conde et al., 2003[31]	Dentifrice	Five dentifrices most commonly used in Brazil were evaluated (1000 to 1500 ppm F). All of the dentifrices were manufactured in Brazil. MFP was present in 100% of the samples analyzed. All dentifrices contained a total soluble fluoride (TSF) concentration greater than 1000 ppm F to provide an anti-caries effect.
Chile	Fernández et al., 2017[32]		Thirty dentifrices commercially available in the three main chain drugstores in Chile were evaluated. Eighteen dentifrices targeting the general public (1100 to 1450 ppm F) contained 78% NaF, 17% MFP, and 5% NaF/MFP. Twelve dentifrices targeting children (422 to 1100 ppm F) contained 58% NaF and 42% MFP. Among dentifrices targeting children, only 25% contained > 1000 ppm F. A total of 42% of dentifrices had low fluoride concentrations (422 to 475 ppm F) with MFP and $CaCO_3$ as abrasives, thus lowering the TSF further. Two dentifrices contained NaF with $CaCO_3$ as abrasive (incompatible, decrease soluble fluoride).
Peru	Chavez et al., 2019[33]		Twenty-three dentifrices, of which four did not have fluoride and 19 had fluoride in concentrations ranging from 452 to 1450 ppm F, targeting children were evaluated (Lima, Peru). All of the dentifrices were manufactured in Ecuador, Peru, USA, China, Mexico, Brazil, and Spain. NaF was present in 70% of the samples analyzed and MFP was present in 30%. Most dentifrices exhibited total fluoride (TF) concentration equal to that mentioned on the label. However, one dentifrice exhibited a concentration of 515.1 ppm F, despite advertising 1450 ppm on the packaging. The majority of children's dentifrices were fluoridated, although only 53% contained a TSF concentration greater than 1000 ppm F (necessary for anti-caries effect).
Uruguay	Loureiro et al., 2017[34]		Six commercial brands of children's dentifrices available in Uruguay were tested (500 to 1100 ppm F). The dentifrices were manufactured in Uruguay, Mexico, and Brazil. NaF was present in 83% of the samples analyzed and MFP was present in 17%. Two dentifrices contained NaF with $CaCO_3$ as abrasive (incompatible, > 50% fluoride insoluble). One dentifrice was formulated with MFP and CaCO3 as abrasive (compatible). Three dentifrices contained NaF and Silica, resulting in TSF concentration similar to TF. Only 33% contained a TSF concentration greater than 1000 ppm F (necessary for anti-caries effect).
Brazil	Iwakura and Morita, 2004[35]	Mouth-rinse	1970s - The role of fluoride mouth-rinse programs in caries control strategies was re-evaluated. In Brazil, the application of 0.2% sodium fluoride mouth-rinse has been one of the most commonly used methods of preventing caries after the fluoridation of public water supply. In Londrina (water fluoridation started in 1972), Paraná State, the weekly fluoride mouth-rinse program (which completed 20 years in 2001) targeted 248,872 school children aged 6 to 12 years. 2001 - The results showed that the fluoride mouth-rinse program (twice/week using 0.2% sodium fluoride mouth-rinse) was not associated with a lower prevalence of caries, both in public and private schools.
Brazil	Arruda et al., 2012[36]	Varnish	A great heterogeneity in the distribution of dental caries was observed, further complicated by inequalities in access to fluoride, particularly in rural communities. Fluoride varnish (5% NaF) application was evaluated.
Chile	Palacio et al., 2019[37]		A decision analytic model (DAM)-based cost-effectiveness analysis aimed to evaluate the costs and effects (in terms of caries prevalence) of a Chilean fluoride varnish program. Cost was found to be a limitation.
Dominican Republic	Abreu-Placeres et al., 2019[38]		A randomized clinical trial (including 180 children aged 6 to 7 years and considered to be at high risk of developing caries) evaluated the effectiveness of fluoride varnish (FV) application in the prevention of carious lesions on erupting first permanent molars. Groups evaluated: (i) control, (ii) FV applied every 3 months, and (iii) FV applied every 6 months. FV application every 3 months reduced the risk of developing caries lesions to a greater extent than FV application every 6 months and the control group.
El Salvador	Dabiri et al., 2016[39]		A rural community-based program (Asociación Salvadoreñna Pro-Salud Rural - ASAPROSAR) evaluated the use of fluoride varnish application as a preventive measure for dental caries.

*Although the key focus of the publication is exposure to fluoride, we carried out a critical review of strategies for the use of fluoride in LACCs.

Table 3. The use of occlusal sealants for dental caries control in Latin American and Caribbean countries (LACCs).

LACC	Authors	Summarized findings
Brazil	Goldman et al., 2017[40]	Children (aged 6–7 years) from public primary schools in a low socioeconomic area of Paranoá city, Brasilia, Brazil, participated in this study.
		A 3-year cost-effectiveness analysis was carried out to compare the ability of composite resins, atraumatic restorative treatment (ART) using high-viscosity glass-ionomer cement sealants, and supervised tooth-brushing to prevent cavitated dentine carious lesions in high risk first permanent molars.
		The results showed that supervised tooth-brushing had lower costs and higher savings per cavitated dentine carious lesion prevented compared to composite resin and ART sealants.
Chile	Espinoza-Espinoza et al., 2019[41]	The analysis model showed that the universal application of resin sealants as part of school-based sealant programs in Chile would be a cost-effective measure in populations where the prevalence of caries in first permanent molars was high.
		Public policies should include the application of sealants in children from low-income families where caries risk is high.
Colombia	McCune et al., 1979[42]	Children (aged 6–8 years) from public schools in Medellin, Colombia, participated in this study. The half-mouth technique was used to place occlusal sealant, with the contra-lateral tooth serving as a control. Evaluations were conducted 24 and 36 months after sealant placement.
		The incidence of caries in all sealant-treated teeth at 36 months was 8% compared to 53% in the untreated control teeth, suggesting that sealants were effective in protecting the occlusal surfaces of teeth against caries.
Costa Rica	Ulate Jiménez and Montero Salazar, 2007[43]	Costa Rican children aged 12 years and going to public or private schools were examined for the presence of at least one sealant on one of their permanent teeth.
		The prevalence of pit and fissure sealants was 60% in the central region of the country, and less than 30% in other areas of the country.
Mexico	Luengas-Quintero et al., 2013[44]	2001 - 2006 - The National Oral Health Program of Mexico included the use of ART sealants (high-viscosity glass-ionomer cements) for caries-prone pits and fissures.
		2008 - 2012 - The National Development Plan and the National Plan for Health reinforced the use of ART sealants as a caries control approach.
		The dentine carious lesion failure rates for the use of ART sealants in primary and permanent teeth over the 2-year period were 0% and 2.5%, respectively.
	Soto-Rojas et al., 2012[45]	Study developed as an international service-learning program targeting small rural communities in Calnali, Hidalgo, Mexico.
		Resin-based sealants placed in children (aged 6–15 years) living in a rural setting.
		The high prevalence of caries in this rural population suggests that there is still a great need for comprehensive dental public health programs.
Peru	Pachas Barrionuevo et al., 2009[46]	The study assessed the survival rates of ART sealants applied on the occlusal surfaces of permanent molars and premolars in schoolchildren (aged 8–13 years) from a public school in Lima after a 2 year intervention follow-up.
		The use of the ART technique has shown encouraging results for the prevention of dental caries. It can be implemented in populations living in rural and marginal urban areas.
Venezuela	Fox et al., 2012[47]	Action research was applied as a strategy for caries control during the development of the Oral Epidemiological Profile study. This included Atraumatic Restorative Treatment (ART), considered to be an effective and economically feasible technique for vulnerable communities.

that replacement of sucrose in chewing gums with Xylitol was the most effective method of reducing caries in school children, followed by sorbitol or a combination of both. Importantly, favorable outcomes were seen to be more pronounced when the comparator group was "no gum control." These studies were mostly conducted by researchers based in the United States and Finland. All five studies that reported adopting educational strategies were carried out in Brazil, with 3 of them reporting on the same intervention. The educational approaches mostly involved parental counseling on feeding practices during early childhood through community interventions,[13] and the majority reported significant reduction in caries rates. Some of the studies focusing on interventions restricting sugar exposure did not measure caries outcomes and used proxy variables instead. Moreover, none of the studies investigated the effects of these interventions in adults or older adult populations in the region.

Interventions based on fluoride use for caries control were mainly adopted in the following LACC: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador,

El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela (Table 2). Of these, the majority of the publications reported on fluoride use in Brazil (7 studies) and Chile (4 studies), while the remaining countries all had at least one study reporting fluoride-based interventions.

The main fluoride-based strategies used drinking water, refined domestic salt, cow milk, and toothpastes, while community-based interventions utilizing mouth-rinses, gels, and varnishes were documented to a lesser extent (Table 2). Although our searches identified many publications examining soluble fluoride content in commercial dentifrices used by the population, this review only included the four studies that were carried out in LACC (Brazil, Chile, Peru, and Uruguay). The remaining relevant studies included in this report focused on the use of fluoride varnishes in Brazil,[36] Chile,[37] Dominican Republic,[38] and El Salvador,[39] and on the use of a combination of fluoride mouth-rinses and APF gels in Brazil[18,35] and Peru[30]. Some publications were more comprehensive and documented several strategies for fluoride use within the same country, such as in Chile,[17] Cuba,[16] Brazil,[18] Colombia,[29] Haiti,[19] and Peru,[30] or reported one or more strategies adopted in several LACC.[20,26,27] The remaining studies reported one specific strategy adopted in a single Latin American and Caribbean country.

Interventions based on the use of occlusal sealants for caries control (Table 3) were adopted in Costa Rica[43] and Mexico.[44,45] The remaining studies mainly evaluated the use of occlusal sealants in local settings, focusing mainly on children at high risk of developing caries and belonging to lower socioeconomic strata or rural areas of Brazil,[40] Chile,[41] Colombia,[42] Peru,[46] and Venezuela.[47]

Discussion

This report summarized the main scientifically documented community interventions and strategies based on restricted exposure to sugars, use of fluoride, and use of occlusal sealants for caries control in Latin American and Caribbean countries (LACC). The majority of the evidence focused on strategies based on fluoride use, and the results of this review are important in the context of the changes in our understanding of dental caries and possible ways to control it, defining new perspectives to control the disease in LACC.[48] Dental caries, previously considered to be a transmittable infectious disease, has now been clearly understood as a non-communicable disease that can be controlled.[1] This paradigm shift is also reflected in the strategies employed by LACC to control the disease.

Although fluoride has been considered as an effective agent for the control of dental caries since the 1930s, the role of exposure to sugars in caries development was only re-emphasized recently. While biofilms are ubiquitous on teeth and are constantly forming, bacteria can only produce acids that are responsible for tooth demineralization and formation of caries upon frequent exposure to sugars.[49] Therefore, effective caries control strategies must include components targeting sugar consumption. It is also essential to differentiate lesion management from disease control, as limiting lesion progression through a restorative approach will only act at the tooth level. Disease control measures, however, must target behavioral, dietary, and hygiene factors for a more holistic approach. Among the dietary carbohydrates, sucrose favors the faster growth of biofilms and changes in their matrix that contribute to higher acidogenicity which, in turn, leads to increased tooth demineralization.[4] However, intervention strategies based on the restriction of sugar exposure are still scarce in LACC (Table 1), and the three main approaches adopted so far are education, sugar replacement, and food supplementation. In 2015, WHO released a guideline with recommendations on the intake of free sugar to reduce the risk of non-communicable diseases such as obesity, diabetes, and dental caries in adults and children.[50] Products containing high concentrations of sugar and poor nutritional content usually tend to be cheaper and are, therefore, more frequently consumed by the population, particularly low-income families. However, the limited number of studies reporting interventions based on restricting sugar exposure in LACC has made it difficult to understand the impact of these interventions in these countries, taking into consideration contextual factors.

Further research in the field of educational programs intended to reduce the burden of untreated caries as well as studies examining the impact of these interventions in older populations are necessary.

Even though food supplementation with probiotics or putative anti-caries nutrients[51] appears to be an attractive approach for caries control, there is limited evidence on their efficacy. Taking into consideration the difficulty of effectively controlling sugar intake in the Latin American and Caribbean region, reducing cariogenicity within a cariogenic background while taking sociocultural factors into consideration may represent an opportunity for caries control. Sugar replacement using alternatives such as chewing gums containing Xylitol appear to have more grounds for appropriate caries control, at least in children.[12] The majority of studies exploring this were conducted several years ago in Belize by the same group of researchers who reported long-lasting effects of administration of polyol gums five times per day for more than 3 years. However, a recent systematic review conducted by Riley et al.[52] reported insufficient evidence on the effectiveness of xylitol-containing products in controlling caries, based on the low to very low-quality of evidence available on it.

Finally, education seems to be the most rational approach to controlling caries. Most programs reported in LACC have achieved caries reduction in young children through the provision of home or school-based education.[13] Additionally, educating parents on correct feeding practices from early life also proved to be advantageous as it prevented the onset of diseases and ensured healthy behavioral and dietary practices that would likely persist throughout the life course. Some of the interventions reported also included provision of oral hygiene education, including reinforcement of tooth-brushing habits to mechanically remove the biofilm present on teeth. Although tooth-brushing alone without the use of fluoride dentifrices have limited effect on caries control,[53] daily disruption of the biofilm was seen as a desirable practice.

Although interventions at the individual level by dental professionals are important for maintenance of good oral health, restriction of exposure to sugar requires intercession at the public policy level and there have been some recent developments in this area in LACC. For example, policies proposing food labeling were recently approved in Chile, México and Ecuador, and initial assessment of their effects suggest positive outcomes.[54] Chile first implemented a food labeling program, wherein high-sugar foods (as well as saturated fats, calories, and salt) were labeled with a black stop sign,[55] and it has since been reported that the purchase of such products decreased by 23.7%. This was significantly higher than the effects of a sugar tax, a measure adopted in various countries around the world as well as in the LACC region (including Chile and Mexico). The findings of this review highlight the importance of incorporating measures restricting sugar exposure in every caries preventive program and also reinforce the need for further research in this area. As individualistic, clinical, and educational preventive approaches fail to tackle the underlying cause of disease, researchers have postulated that priority should be given to investment in upstream, coherent, and integrated population-wide policies such as taxes on sugary drinks and stronger regulation of advertising and promotion of sugary foods and drinks targeting children.[56]

Of the various fluoride delivery strategies available, the use of fluoridated water or salt were found to be the most popular options in LACC as both approaches allowed intervention at a wider community level. Several countries such as Argentina, Brazil, Colombia, Cuba, Ecuador, Jamaica, Panama, Peru, and Chile authorized fluoridation programs and began implementation in water treatment plants of certain cities; however, of these, only Brazil and Chile managed to achieve extensive coverage (Table 2). This was mainly because many countries chose to adopt salt fluoridation programs instead, based on PAHO's Regional Oral Health Plan,[57] although the extent of coverage has not been documented. Moreover, some studies have shown that salt samples did not meet the required specifications[24,25,29] and were also sold in areas with drinking water already containing optimal natural levels of fluoride for caries prevention,[21] leading to increased incidence of dental fluorosis.[23] A greater understanding of the natural occurrence of fluoride in water and the difficulties associated with limiting the commercialization of fluoride salt in these areas

led to concerns regarding increased risk of dental fluorosis and the emergence of timely surveillance systems in many countries.[14,22,29,30] Preventing multiple sources of fluoridation can only be achieved through policy decisions that approve regulatory mechanisms maintained by governmental institutions. Dental fluorosis is a late marker of excessive fluoride exposure, making implementation of surveillance systems focusing on the intake and quality of drinking water and other sources of fluoride necessary. Such systems must take advantage of the information and communication technologies available in order to expand their use at various levels of society. In this context, it is possible that the adoption of digital health technologies can play an important role in achieving some of the Sustainable Development Goals,[15] one of which aims to achieve universal and equitable access to safe drinking water for all by 2030.

The concentration of fluoride in water represents a basic parameter for the assessment of its quality and safety as sub-optimal levels may increase the risk of dental caries while above-optimal levels may lead to dental fluorosis.[58] Although some LACC have clear policies on the use of fluoride, there are still many that do not, suggesting the need for prioritization of investigations into the natural occurrence of fluoride in water and the development of measures necessary to achieve levels optimal for caries prevention.[9] Where this is not possible, population-wide strategies such as fluoridated salt or milk should be considered as the possibility of two or more simultaneous sources of fluoride intake can then be eliminated or reduced.[29]

Water and salt fluoridation programs have contributed significantly to the decline in dental caries observed in LACC. However, for several reasons beyond the scope of this article, these strategies are often not homogeneously implemented in all regions of the countries and, therefore, sometimes do not reach the populations most vulnerable to the development of caries. Greater professional advocacy and involvement of other sectors representative of the populations are necessary in order to drive governmental actions necessary for the expansion of these programs where appropriate and re-assessment of public policies where they have been implemented already. Remote and rural areas are seldom favored by these programs, and urgent development and implementation of customized interventions are necessary. The use of fluoridated milk as a community level intervention has been reported in some rural areas of Chile.[17] However, targeting culturally appropriate, economically sustainable caries control interventions to rural populations and native ethnic groups such as indigenous people (> 45 million and over 800 ethnic groups), quilombolas (African-origin), and riverside Amazonian people remains a crucial challenge.

Fluoride dentifrices are another globally popular strategy for caries control[59] as they represent the most rational individual level approach that promotes biofilm removal during tooth-brushing while simultaneously delivering fluoride into the oral cavity. The mechanical removal of dental biofilm by daily tooth-brushing not only controls the development of dental caries but also helps in the prevention of periodontal diseases. A single episode of manual tooth-brushing may reduce dental biofilm up to 42%.[60] It is also noteworthy that complete removal of the biofilm is challenging, especially in areas of the mouth that are difficult to access while brushing and, therefore, are more susceptible to disease. Therefore, daily release of fluoride into the oral cavity via dentifrice formulations represents a necessary strategy for caries control and should be encouraged regardless of the presence of water or salt fluoridation programs. Moreover, additives have been incorporated into fluoride toothpastes in an attempt to improve its anticaries effect. These substances include arginine, baking soda, calcium glycerophosphate, CPP-ACP, CPP-ACPF, and sodium hexametaphosphate. Promising findings have been reported for some of them. Hence, there is good reason to believe that new technologies should be investigated further as they have the potential to complement and enhance the effects of fluoride and reach the status of effective innovations in caries prevention.

A common characteristic of most commercially available dentifrices in LACC is the use of calcium carbonate ($CaCO_3$) as abrasive (Table 2). This is mainly because it is cheaper than silica and is, therefore, more widely used, particularly in low-income families , being an affordable toothpaste formulation.[61] However, $CaCO_3$ abrasive is only compatible with monofluorlophosphate (MFP) as chemically soluble fluoride tend to remain

stable in its presence. The ion fluoride present in sodium fluoride (NaF), stannous fluoride (SnF_2), or amine fluoride (AmF) react with the calcium present in $CaCO_3$ abrasive, dramatically, decreasing the soluble fluoride concentration and resultant anti-caries effect. Despite this interaction is a well-known fact, NaF was detected in several $CaCO_3$-based dentifrice formulations sold in Chile[32] and Uruguay,[34] raising questions regarding the amount of soluble fluoride present in the formulations. In addition to an increase in the amount of non-fluoridated dentifrices available in the market, there are also a wide range of formulations with low concentrations of fluoride which certainly affect their potential to control caries. Consequently, proper legislations[62] that regulate the amount of soluble fluoride present in dentifrices targeting adults as well as children so as to achieve optimal levels for caries control are necessary in LACC. Evidence shows that use of dentifrices containing at least 1000 ppm of fluoride twice per day is highly effective in caries prevention,[63,64,65] emphasizing a need to encourage their use in the population.

Other less frequently reported approaches of fluoride delivery in LACC include mouth-rinses, APF gels, and varnishes. Fluoride mouth-rinses have been adopted as an individual level, school-based intervention in Brazil[18,35] and Peru,[30] although it is likely that they were also implemented in other LACC. The preventive effect of mouth-rinses has been reviewed as other fluoride sources (*e.g.*, water, salt, toothpaste) may be present, contributing to caries control.[65] APF gels and fluoride varnishes represent a professional approach to fluoride delivery, and studies reporting their use in LACC did so in the context of specific populations only and not in a clinical environment. School-based programs incorporating APF gel application as a complementary approach for mouth-rinses have been reported in Brazil[18] and Peru,[30] while the use of fluoride varnishes as a desirable preventive public health measure targeting high-caries-risk populations living in remote and rural areas without access to fluoridated salt or water have been reported in Brazil,[36] Chile,[37] and El Salvador.[39] Although fluoride varnishes may represent a feasible public health program for this specific population, the associated costs make them a less-suitable approach in comparison to the alternatives.

Occlusal sealants have also been used as a strategy for caries control in several LACC (Table 3) such as Costa Rica[43] and Mexico[44], being also used in the management of caries lesions.[66] One study from Costa Rica evaluated 12-year-old students across the country and found widespread use of occlusal sealants.[43] The National Oral Health Program developed in Mexico in the early 2000s also included occlusal sealants as a strategy for caries control and mainly targeted rural communities.[45] Occlusal sealants have been proposed as a feasible strategy for children at high risk of caries and living in remote and rural areas without access to fluoridated salt or water. The most commonly used sealant materials were found to be either resins or high-viscosity glass-ionomer cements, the latter being the preferred option in LACC areas with limited access to a proper clinical environment as they can be administered as an atraumatic restorative treatment (ART).[40,44,46,47] Incorporation of this approach at an individual and community level as an initial intervention complementing a wider approach including education of the population, minimizing biofilm accumulation, and restricting sugar exposure is recommended. Documented community-based strategies for caries control using occlusal sealants were scarce in LACC except for Costa Rica and Mexico.

Conclusion

Dental caries occurs due to frequent exposure of the dental biofilm to sugars which, in turn, is also related to the development of other non-communicable diseases that can have a negative impact on the individual's health and quality of life. However, this can easily be avoided through public policies that implement evidence-based strategies to control sugar consumption in an affordable manner and targeting all population groups instead of the most affluent only. Despite widespread use of biofilm control as a regular oral hygiene measure, the prevalence of caries remains high in LACC suggesting the need for strategies that incorporate multiple approaches. Although fluoride has been shown to have anticaries potential in the presence of frequent exposure to sugars, its preventive efficacy could be higher if combined with activities to restrict sugar consumption. Fluoride delivery should

be extended to the community level using water and salt, although this should also be accompanied by adequate surveillance systems. Regulating the concentration of soluble fluoride (for anticaries effects) in dentifrice formulations is necessary in order to provide the population with an effective strategy for disease control. Although the use of sealants has also been found to be effective in caries control, a thorough understanding of the disease and the role of biofilm accumulation and sugar consumption at the individual level is necessary. It is essential that each Latin American and Caribbean country understands how the various strategies may be implemented or improved at the individual, local, and/or national levels so as to suit their population needs.

Prospects for Latin America

Better awareness of the association between frequent consumption of sugars and dental caries formation must be developed through widespread dissemination of information in LACC, and strategies to reduce sugar consumption should be encouraged at the individual and community levels. Local and/or national policies should be implemented keeping in mind the sociocultural identity of each Latin American and Caribbean country, and further investment should be made in upstream, integrated population-wide strategies such as taxes on sugary drinks, and stronger regulations on advertising and promotion of sugary foods and drinks targeting children. This will not only help control dental caries incidence but also improve the overall health of the population by preventing other non-communicable diseases such as obesity, diabetes, and cardiovascular diseases.

Although the use of fluoride to control dental caries has contributed to the reduction in prevalence of dental caries in LACC over the years, its use must be monitored at the local, regional and national levels so as to achieve maximum anti-cariogenic effects while also minimizing the risk of dental fluorosis. Moreover, fluoridated water and salt programs, used as a mutually exclusive community level strategy for caries control, should expand their benefits to reach non-recovered areas of LACC while also simultaneously providing adequate surveillance of the fluoride concentration delivered to the population. Areas with two or more simultaneous sources of fluoride intake should have one of the sources eliminated or reduced.

Although the use of fluoride dentifrices during tooth-brushing is a practice well-embedded in most urban population groups, it should also be promoted as a community level strategy among school children, rural populations, and traditional LACC groups (e.g., indigenous, quilombolas, and riverside Amazonian people) through culturally appropriate and economically sustainable policies and programs. The dentifrice formulations must have optimal levels of soluble fluoride to ensure an anti-caries effect, and the lack of specific legislations regulating the minimum concentration of fluoride in dentifrices in LACC should be addressed. The use of fluoride and occlusal sealants through individual or community level intervention programs should be incorporated into wider strategies addressing sugar consumption and biofilm control. Mouth-rinses, gels, and varnishes can be included as vehicles for fluoride and occlusal sealants in a well-planned program that combines population strategies aiming to shift the distribution of risk factors in the entire population as well as those at the highest risk of disease. Targeting culturally appropriate, economically sustainable caries control interventions to rural populations and native ethnic groups such as indigenous people, quilombolas (African-origin), and riverside Amazonian people remains a crucial challenge.

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Management of dental caries lesions in Latin American and Caribbean countries

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Abstract: Caries management at the lesion level is dependent on the lesion activity, the presence of a cavitation (either cleanable or non-cleanable), and lesion depth as evaluated via radiographic examination. A variety of non-invasive, micro-invasive, and minimally invasive treatment (with or without restoration) options are available for primary and permanent teeth. Non-invasive strategies include oral hygiene instructions, dietary counseling, and personal as well as professional use of fluoridated products that reduce demineralization and increase re-mineralization. Micro-invasive procedures include the use of occlusal resin sealants and resin infiltrants, while minimally invasive strategies comprise those related to selective removal of caries tissues and placement of restorations. Deep caries management includes indirect pulp capping, while exposed pulp may be treated using direct pulp capping and partial or complete pulpotomy. The aim of the present study was to review available evidence on recommended preventive and restorative strategies for caries lesions in Latin American/Caribbean countries, and subsequently develop evidence-based recommendations for treatment options that take into consideration material availability, emphasize ways to adapt available treatments to the local context, and suggest ways in which dentists and health systems can adopt these treatments.

Keywords: Dental Caries; Evidence-Based Dentistry; Latin America; Caribbean Region.

Introduction

The lack of consensus on dental caries management was recently recognized during a discussion between various expert authors from the Latin American and Caribbean countries (LACC), and the aim of this review was to address this gap by developing relevant evidence-based recommendations and strategies that took geographical factors as well as the patient's individual needs into consideration. Therefore, a critical literature review of international evidence, with a specific focus on studies conducted in LACCs, was carried out using a narrative strategy, and the research question of interest was as follows: *What are the best treatment options currently available for the management of caries lesions in LACCs?*

Dental caries is a multi-factorial, non-communicable, non-infectious, chronic, biofilm-induced disease modulated by various biological,

behavioral, psychosocial, and environmental factors.[1] Caries lesions are typically characterized by the active loss of tooth minerals, induced by the metabolic activity of dental biofilm formed by frequent consumption of a sugar-rich diet. In the absence of any intervention, the cumulative effects of alternating demineralization and re-mineralization cycles (favoring the former) leads to the development of a clinically visible lesion,[2,3] and defensive reactions such as increased intra-tubular dentin formation and initial pulpitis may occur in the dentin-pulp complex upon lesion progression.[4] When left untreated, caries lesions may slowly progress into the deep dentin and pulpal tissue and, in severe cases, profoundly affect the general health and decrease the quality of life of the patients.[5] Severe caries lesions represent the primary cause of oral pain and tooth loss globally.[6]

Despite significant advances in oral-health sciences, the World Health Organization have highlighted the high prevalence of dental caries in various developing countries and particularly those in the LACC region where caries represent a major unmet need of the population.[7] Numerous studies have reported prevalence rates of 40% to 90% among children, teenagers, and adults in this geographic region,[8] and the management of dental caries is often beyond the financial capabilities of low-income countries where limited resources hinder access to high-quality dental treatments.[9] Therefore, better use of financial resources through the development of evidence-based protocols recommending non-invasive or minimally invasive restorative treatments is essential.

Dental caries need to be managed at the patient and lesion levels. Patient-level interventions include non-invasive strategies that aim to control disease progression and lesions becoming clinically detectable. This can be achieved through dietary counseling and comprehensive oral hygiene measures such as mechanical removal of the dental biofilm through daily tooth-brushing using fluoridated dentifrices which promote re-mineralization by re-establishing the mineral balance between the tooth surface and the surrounding aqueous phase (represented by the saliva and dental biofilm fluid).[2] However, the success of these interventions is directly dependent on patient adherence to the treatment protocol, and it has been suggested that the best practice for dental caries management should include a more patient-centered model consisting of individualized caries risk assessment and early detection of non-cavitated caries lesions. This approach aims to achieve personalized treatment for the individual patient, and focuses on the treatment and prevention of dental caries at the patient level.[10]

Dental caries management at the lesion level includes a wide range of non-invasive, micro-invasive, and minimally invasive interventions that vary depending on the lesion activity, presence of cavitation (cleanable or non-cleanable), and lesion depth (shallow/moderate/deep - evaluated using radiographic examination).[3] These interventions aim to arrest lesion progression, preserve pulpal health by creating a hermetic seal against microbial invasion (through placement of a restoration), and re-establish the tooth's structure and function for as long as possible.[11] The management protocol for deep caries lesions with a high risk of pulp exposure should include selective removal of caries tissues followed by the placement of new and improved pulp capping biomaterials if necessary.[12] This contemporary approach to management of caries lesions results in less expensive and more predictable outcomes from the histological and clinical points of view.[4]

Therefore, this review aims to describe current strategies for the management of dental caries at the lesion level for primary and permanent dentition, and make evidence-based recommendations targeting dental practitioners in LACCs.

Strategies for the management of caries lesions: Scientific evidence from LACCs

A direct comparison of studies was hindered by the lack of consensus on the management of caries lesions and variations in methodologies and study designs adopted. Therefore, prior to commencement of the evidence-based review, the authors first defined the primary objective by means of a set of questions focusing on the management of all caries lesions (ranging from non-cavitated lesions to deep cavities) while taking socioeconomic and cultural factors of LACCs into consideration.

Based on evidence from various clinical trials (some of which were conducted in LACCs), practitioners and health policy-makers should adopt caries management strategies that take the depth of the

lesion into consideration as these techniques tended to be cost-effective and could, therefore, be adopted by conventional public dental health service in LACCs. This would be particularly beneficial for the enhancement of oral-health care in deprived communities by increasing accessibility to preventive and restorative treatments. Some of the strategies for caries lesion management have been presented below.

Selection of an appropriate strategy should begin with a careful and precise diagnosis at the lesion level. Inactive lesions are typically characterized by the presence of shiny whitish/brownish areas of discoloration on non-cavitated lesions as well as of shiny, smooth, hard on gently probing, and discolored brownish in cavitated lesions reaching dentin. These lesions typically do not require any intervention other than monitoring as they are disease scars, although restorations can be placed in cavitated lesions in order to protect the pulp-dentin complex or restore the tooth's function, form, and esthetics.[13]

Conversely, opaque, rough and whitish tissue on non-cavitated lesions and the presence of soft or leathery (to gently probing) humid and yellowish/light-brownish tissue in cavitated lesion reaching dentin are clinical signs of active lesions that need to be controlled. Clinicians must be trained to identify early signs of active demineralization which will enable them to intervene in a timely manner using non-invasive and micro-invasive strategies. For cavitated lesions, it is essential to first take into consideration whether the cavity can be cleaned or not as it will help with the decision-making process and selection of the best treatment strategy. Non-invasive strategies are sufficient for the management of cavities that can be cleaned, while those that cannot be cleaned may require a combination of non-invasive, micro-invasive, or minimally invasive strategies coupled with restorations. This decision-making process should be biologically informed, evidence-based, and should take the needs of the patient into consideration.

Management of non-cavitated lesions—Non-invasive/micro-invasive strategies

The primary prevention of dental caries typically involves inhibition of lesion initiation as indicated by the recent consensus on the term dental caries care/management/control as "all actions taken to interfere with mineral loss at all stages of the disease process" This includes primary, secondary, and tertiary preventive measures that incorporate both non-operative and operative treatments.[1]

Disease triggering factors must be controlled in order to prevent formation of caries lesions and arrest progression of existing ones. Therefore, preventive strategies should take biological, behavioral, psychosocial, and environmental factors into consideration in order to avoid negatively affecting the oral environment.[14] Oral hygiene measures, dietary counseling, and other non-invasive strategies (such as the application of fluoride and chlorhexidine varnishes and the use of xylitol lozenges) have been shown to be effective in controlling active non-cavitated lesions in children.[15] Some of these strategies will be reviewed in the subsequent section to highlight the need for simultaneous management of the disease and lesion.

Various experimental and clinical studies have demonstrated that caries lesions originate in the enamel or exposed root dentine beneath accumulated and stagnated dental biofilms. The dental caries process initiation and progression depend on the metabolic activity of the dental biofilm which, in turn, is enhanced by frequent intake of dietary sugars. Therefore, regular and meticulous mechanical removal of the dental biofilm aids in arresting lesion progression.[16] However, previous studies have shown that personal oral hygiene protocols (by means of supervised tooth-brushing) lacking fluoride administration, either via dentifrices or community-based methods, were effective in controlling gingivitis but failed to prevent coronal caries in children aged 10-13 years old.[17] This reinforces the importance of fluoridated products (*e.g.* dentifrices) and/or community-based methods for fluoride delivery in lesion control.

The selection of appropriate strategies for the prevention of lesion formation and inhibition of disease progression can be challenging for the dental professional, and the decision-making process should be based on scientific evidence focusing on when and how to implement the strategy while taking the needs of the patient and the availability of financial and technical resources, especially in public health systems, into consideration. Selection of multiple

strategies may be necessary, and the risk of caries exhibited by the patient may even be considered on the decision-making process.[18]

The recent global decrease in the prevalence of dental caries can be attributed to the widespread use of fluoride-containing dentifrices,[19,20] with numerous clinical studies showing that mechanical removal of the dental biofilm by daily tooth-brushing using fluoridated dentifrices in concentrations of 1,000–1,500 ppm F significantly contributed to controlling enamel, dentin, and/or root caries lesions.[20-23] Moreover, tooth-brushing twice a day using fluoride dentifrices at concentrations of 5000 ppm F was shown to be more effective in arresting root caries in the elderly population compared to dentifrices with concentrations of 1,000–1,500 ppm F.[23,24] Professional dental biofilm management should be also considered as a treatment option for dental caries.

In addition to dentifrices, a wide range of topical fluoride-based agents are available for individual use,[25] including high-concentration fluoride products (such as acidulated phosphate gels, varnishes and solutions) which allow deposition of greater amounts of calcium fluoride globules onto the tooth surface forming fluoride reservoirs in the oral cavity. Progression of non-cavitated caries lesion in primary and permanent teeth can be significantly controlled by 5% NaF varnishes,[26] while 38% silver diamine fluoride (SDF) represent a more effective strategy for the control of cavitated caries lesions reaching dentine when compared to other active treatments (e.g. atraumatic restorative treatment (ART) restorations or NaF varnish).[27] SDF has also been shown to be effective in inactivating root caries lesions.[24,28,29]

Among non-fluoridated agents, casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) is a bioactive agent that has been shown to be effective in re-mineralizing tooth structures *in vitro* and *in vivo*. A recent meta-analysis suggested that CPP-ACP, conventional fluoride toothpastes, and fluoride varnishes had similar efficacy with regard to controlling lesion development, and clinical parameters such as enamel micro-hardness, DMFS/dmfs (decayed, missing, filled surfaces) index scores, and Enamel Decalcification Index scores did not differ significantly between CPP-ACP and fluoride products.[30] Moreover, a combination of CPP-ACP and fluoride varnish was shown to have superior anti-caries effect, particularly in enamel lesions on young permanent teeth, as CPP-ACP could carry fluoride ions deeper into the lesions, enhancing re-mineralization. Nevertheless, there is insufficient evidence on whether CPP-ACP agents are more effective in controlling caries lesions when compared to fluorides, and high quality, well-designed randomized controlled trials are necessary.[30]

The cariostatic effects of non-fluoridated chemical agents such as arginine, chlorhexidine, triclosan, and xylitol have been evaluated *in vivo* and compared with conventional fluoride in several randomized controlled trials. A recent systematic review compared the efficacy of non-fluoridated agents and fluoride in controlling caries in primary teeth and found no evidence of the former being superior. However, this could be attributed to a high risk of bias in most studies reviewed,[31] and well-designed randomized controlled trials are necessary in order to make conclusive recommendations. Chlorhexidine varnish was found to be more effective in controlling root caries lesions compared to placebos, and the results were consistent.[32]

An *in vitro* study examined the use of theobromine (3,7-dimethylxanthine), a primary alkaloid derived from the cacao plant commonly found in LACCs, as a re-mineralizing component of dentifrices and found it to be less effective than those containing fluoride.[33]

The use of nanotechnology to enhance the anti-caries effects of dentifrices, varnishes, surface coating agents, and fluoride-releasing materials have also shown promising results, with the use of oral medicine nano-systems for individual prophylaxis showing significant progress with regard to ensuring bacterial symbiosis and maintaining good oral health. Nano-particles have also been integrated into various cosmetic products targeting enamel re-mineralization, thus creating opportunities for new research into the development of enhanced delivery systems that serve as carriers for minerals and/or biomaterials. Their clinical use for control of caries lesions remains under evaluation.[34]

Current evidence also recommends the use of pit and fissure sealants as a micro-invasive strategy for the prevention and control of caries lesions.[24] Resin-based fissure sealants act as a physical barrier between the tooth surface and the stagnated dental biofilm and

successfully reduce the onset and progression of occlusal caries lesions, particularly in permanent molars.[35] This evaluation is largely based on evidence that shows that sealing a lesion reduces the bioavailability of nutrients to microbial growth, thus preventing disease progression up to 70% in non-cavitated occlusal lesions when compared to no sealing.[35,36] Moreover, sealants are more effective in arresting active non-cavitated occlusal lesions when compared to fluoride varnishes, although there is still no clear evidence on the best sealant (resin-based or glass ionomer).[37] However, the questionable integrity and stability of sealants placed on occlusal lesions that appear non-cavitated clinically but extend into the middle or inner dentine radiographically should be taken into consideration, and a minimally invasive restorative strategy (as described below) should be adopted in such cases.[13]

In contrast to sealants, resin infiltration acts as a barrier not on the tooth surface but within the caries lesion. Filling the enamel lesion, the resin can occlude the porosities, thus preventing the lesion progression by avoiding the penetration of the acids originated in the dental biofilm located on the external tooth surface. Previous studies have shown that resin infiltration is more effective in controlling non-cavitated proximal caries when compared to other non-invasive approaches, both in primary and permanent teeth.[38,39]

Management of cavitated dentine lesions

As mentioned above, the decision-making process for the management of active cavitated lesions is dependent on whether the cavity can be cleaned (where mechanical biofilm removal can be carried out at home by tooth-brushing) or not. The former can be managed non-invasively, and it is assumed that the disease process is halted and lesion progression is arrested upon adequate removal of the biofilm. Accessibility for adequate cleaning can be increased by slightly widening the cavity margins to remove overhanging enamel/dentine.[40] However, patient motivation is crucial in this case, and regular monitoring for proper mechanical removal of biofilm is essential. This is particularly applicable in the case of primary dentition where the child's oral hygiene is the responsibility of their parents or caretakers who must also be adequately informed and motivated. Periodic clinical examination is necessary for assessment of lesion activity, and treatment success is achieved once the remaining tissues become hard indicating halting of lesion progression. The use of 38% SDF solution (applied biannually) as an adjunct to mechanical biofilm removal may be recommended for the management of coronal cavitated caries lesions in primary[25] and permanent dentition.[3] Not all cleaned cavities require restorations, and this method is usually preferred when there is a need to protect the pulp-dentin complex or restore the tooth's function, form, and esthetics.[13]

In contrast, active cavitated lesions that cannot be cleaned, such as those on proximal or other poorly accessible surfaces, are understood to be prone to progression and, therefore, may require restorative procedures facilitating dental biofilm control. Cavities on proximal surfaces or in any other surfaces where the biofilm cannot be properly removed should be assessed by visual-tactile methods (with the aid of tooth separators in the case of proximal surfaces) and/or by bitewing radiographs to assess depth. Proximal cavitation on lesions restricted to the enamel only are unlikely, while lesions extending to the enamel-dentin junction or to the outer third of the dentin may or may not be cavitated and those extending into the middle or inner third of the dentin are likely to be cavitated. Non-cavitated lesions should be managed using non-invasive or micro-invasive interventions as described in the previous section, while cavitated lesions that are difficult to clean should be managed as described below.[13]

Cavitation indicates severe contamination of the dentin with cariogenic microorganisms, although arresting lesion progression is possible through adequate sealing that stopped further microbial growth.[41] Therefore, removal of all caries tissues in order to reach a hard and virtually cleaned and disinfected remaining dentin (non-selective removal of caries tissue up to hard dentin or NSRHD) is no longer promoted, and several strategies for the management of non-cleanable cavitated lesions with dentinal involvement have been presented below. However, it is important to highlight that these are applicable only in case of absence of spontaneous pain, signs of pulpal exposure or irreversible pulpitis, or radiographic evidence of periapical lesions.

Cavitated lesions with dentinal involvement can be managed without prior removal of caries tissue tissues. The Hall technique, which involves placement of a pre-formed metal crown on decayed cavities without tooth preparation (as a mixed non-invasive and restorative treatment) and anesthesia, has been shown to have high success rates in occlusal and occluso-proximal lesions arrestment in primary molars,[42-44] particularly when compared to conventional restorative treatments over 2–5 years of follow-up.[43]

Upon comparing direct placement of resin sealants or flowable resin composites without prior removal of caries tissues (as a mixed micro-invasive and restorative treatment) to conventional composite restorations placed after selective removal to firm/leathery dentine, the two were seen to exhibit similar efficacy with regard to controlling lesion progression in occlusal cavities of primary molars radiographically shown to extend to the outer half of the dentine after 18 months and 2 years of follow-up.[45,46]

Additionally, placement of resin sealants without prior caries tissue removal and conventional resin composite restorations (conducted after removal of all caries tissue) exhibited comparable efficacy on lesions arrestment after 2–3 years[47] and 3–4 years[48] of follow-up of permanent posterior teeth with occlusal lesions (mostly cavitated in enamel and dentin and radiographically shown to extend up to two-thirds of the dentin) requiring restoration. In addition to controlling lesion progression, the placement of resin sealants over caries tissues allows deposition of tertiary dentine on the sealed cavities, thus inducing hardening of the remaining caries tissues.[47,48] An overall comparison of the materials used above showed that flowable resins exhibited survival times that were similar to composite resin restorations.[46] Several studies have reported partial or total loss of resin sealant retention over the studied period,[45,47,48] highlighting the importance of regular follow-up visits for clinical monitoring. The appropriate use of sealants/flowable resins directly over caries tissues in cavitated lesions extending up to the middle third/half of the dentine can postpone the need for more invasive restorative treatments and reduce the need for tissue removal, thus preserving tooth structure. However, further studies in this field are still necessary before a definitive recommendation can be made.

When removal of dentinal caries tissue is unavoidable, it should be kept as minimally invasive as possible to allow good sealing between the restoration and surrounding cavity walls and adequate placement of the restorative material. Moreover, preservation of the tooth structure, maintenance of the pulpal health, and avoidance of pulpal exposure are crucial.[11] It is important to reinforce here that irrespective to the selective removal of carious tissue over the pulp roof (as described below), hard tissue should be left at the cavity surrounding walls (whose tactile characteristics are similar to sound dentin) using hand and/or rotatory instruments for allowing a proper bonding and sealing of the restorative materials with cavity walls. Taking the depth of the lesion and hardness of the remaining dentin into consideration, caries tissues should be removed based on the following recommendations:[11]

a. Shallow to moderate deep lesions where the radiolucency extends to the outer pulpal two-thirds or three-quarters of the dentine (estimated using a bitewing radiograph): selective removal to leathery/firm dentin (SRFD), retention of leathery/firm caries tissue resistant to hand excavator over the pulpal roof, and completion of restoration in one session;
b. Deep lesions where the radiolucency extends to the pulpal third or quarter of the dentin (estimated using a bitewing radiograph): selective removal to soft dentin (SRSD; easily scooped up with a sharp hand excavator) so as to leave some soft caries dentinal tissue over the pulpal roof to reduce the risk of pulp exposure, followed by completion of restoration in one session. For many years, stepwise excavation (SW) was the treatment of choice for such deep lesions. It consisted of caries excavation in two steps, wherein SRSD and temporary restorations were carried out initially, followed by a second round of caries tissue excavation up to firm/hard dentin over the pulpal roof after several months. However, this treatment is no longer being advocated for primary teeth.[49]

Restoration of the cleaned cavity can be carried out using chemically activated high-viscosity glass-ionomer cement (HV-GIC), commonly indicated for ART restoration where the caries tissue is removed with hand instruments only. The decision to remove dentin up to soft or firm consistency over the pulpal roof depends on the lesion depth. A margin of sound dentin (hard tissue) should be retained on the surrounding cavity walls to allow proper sealing, and a sharp hand excavator may be used to widen the entrance of small cavities by removing overhanging enamel. A recent meta-analysis reported high survival rates for single-surface ART restorations carried out using HV-GIC in primary (94.3% over 2 years) and permanent (87.1% over 3 years) posterior teeth. The survival rates for multi-surface restorations were lower in primary (65.4% over 2 years) and permanent teeth (77% over 5 years), although "cavity size" and "cavity depth" were not taken into consideration. The authors concluded that there was insufficient evidence to draw definitive conclusions regarding the survival of multi-surface ART restorations placed on permanent teeth.[50] However, the success of this strategy is directly dependent on the restorative material used. Two clinical trials concluded that ART restoration of primary molars using low-cost GIC presented lower success rates over 1–2 years of follow-up when compared to conventional HV-GIC,[51,52] suggesting that the overall cost of treatment may be increased by the need for re-interventions and replacement of defective restorations.[52] These studies suggest that ART restoration using a high-quality material represented a suitable treatment option for coronal caries lesion management, particularly for single-surface restorations.

Concerns regarding pulpal vitality and the longevity of restorations placed over remaining caries tissues may be raised, especially after selective tissue removal in deep cavities. A similar success rate (assessed both clinically and radiographically) was observed over a 2 year follow-up period for both techniques [selective removal of caries tissue (92%) and NSRHD (96%)] conducted on deep lesions in primary teeth,[53] although the occurrence of pulpal exposure and overall operative time were lower during selective caries tissue removal compared to NSRHD.[53] Moreover, restoration survival was lower for selective removal of caries tissue (66%) compared to NSRHD (86%).[54] A recent systematic review and meta-analysis reported a greater risk of failure for restorations placed after SRSD on primary teeth when both occlusal and occluso-proximal restorations were analyzed together,[55] although the limited number of studies included along with their high risk of bias prevented formation of definitive conclusions.[55] Nevertheless, dentists should not be discouraged from conducting selective removal of caries dentine on deep lesions of primary teeth as this approach allows avoidance of more invasive interventions. Shorter intervals between recall visits to evaluate the quality of restorations has been recommended.[55] A multicenter randomized controlled trial examining permanent teeth for a period of 5 years in public health services and public universities in Brazil showed that pulpal necrosis was less likely to occur after SRDS than after SW on molars presenting deep cavitated lesions radiographically shown to extend beyond the inner half of the dentin thickness.[56] Similar success rates (in terms of pulp vitality) were observed between complete SW (75%) and SRSD (80%) but the success rate of SRSD was higher when both complete and incomplete SW treatments were combined (56%). The authors also reported very low success rates (5%) for incomplete SW, and emphasized that the success of SW is highly dependent on patient commitment to recall visits. Furthermore, as recall visits for SW are associated with cavity re-opening and placement of long-lasting restorative materials, the risk of pulpal exposure during the second step of excavation and related treatment costs and patient discomfort are higher. Additionally, SRSD and restoration in one session exhibited higher success rates with regard to maintenance of pulpal vitality in permanent molars when compared to SW and NSRHD.[57] Given the low risk for pulp exposure, the high success rates in terms of maintenance of pulp vitality over time, and the lower operative time, selective removal of caries tissue followed by definitive restoration in a single visit a recommended strategy for less invasive management of deep lesions. With regard to the longevity of restorations, a 3 year retrospective study examining restoration survival in young permanent

molars of children at a high risk of caries reported similar outcomes for both selective removal of caries tissue and NSRHD.[58] Poor oral hygiene and multi-surface restorations (involving three or more surfaces) were regarded as risk factors for restoration failure.[58] Additionally, restorations placed after SRSD (79%) and SW (76%) exhibited similar success rates after 5 years of follow-up.[59] Generally, resin composite restorations are superior than resin-modified glass-ionomer cements (RM-GIC)[58] and similar to amalgam restorations in terms of longevity.[59] Fracture, loss of marginal integrity, wear, and partial or total loss were the most common reasons for restoration failure,[55,59] and recent studies have suggested that a high risk for developing of caries lesions and the presence of active caries lesions are condition that negatively impact restoration longevity.[58,60]

Dental restorations tend to undergo deterioration and degradation over time, making regular clinical assessments for localized repair or complete replacement if necessary. Restoration replacements often lead to loss of tooth structure, making the tooth remnants more fragile and increasing the risk of harm to pulpal tissue. Hence, attempts to repair defective restorations (*e.g.* by sealing localized marginal defects, polishing, re-contouring) should be considered before opting for immediate replacement. In case of restoration repair, any caries tissue around the defective part should be removed. A retrospective study demonstrated that the repair of defective resin composite or RM-GIC restorations in primary teeth increased their longevity over 3 years, even in high-risk children.[61] Moreover, repaired resin composites (presenting localized defects up to 3 mm diameter and restricted to the occlusal surface) and amalgam restorations (presenting localized marginal defects not wider than 1 mm and restricted to the occlusal surface) acted similarly in terms of marginal integrity and demineralization around the restoration when compared to new restorations in permanent molars over a 10 year follow-up period.[62,63] The anatomy and color of resin composites and marginal staining in case of amalgam restorations were also similar between repaired and replaced restorations, indicating that the former were clinically acceptable even after 10 years.[63,64] These studies suggest that restoration repair increases the longevity of restorations and should be preferred and encouraged where possible. Table shows a summary of studies examining caries management in LACC.[22,45,46,48,51,52,53,56,58,59,64,65,66,67,68,69,70,71,72,73] Figure 1 shows a decision-making diagram for the management of non-cavitated and cavitated dentine lesions in the context of LACCs. These recommendations are intended to assist clinicians and stakeholders in the decision-making process, and it is important to re-emphasize that strategies should be selected based on clinical judgment as well as the patient's needs.

"Ultra-conservative Treatment" (UCT) of caries lesions often involves placement of bound and sealed restorations directly over frank cavitated lesions extending into the dentine.[1] However, it may also include combined use of ART restorations for small cavitated lesions as well as enlargement of medium-sized cavities to facilitate biofilm removal under supervised toothbrusing.[22] These variations in definitions and approaches associated with UCT increased the risk of misunderstanding and as a result this terminology was not included in the present manuscript.

Management of deep caries lesions with exposed pulpal tissue

To avoid further compromising the pulpal tissue, deep caries lesion management should follow scientifically proven approaches. However, in many cases the depth of the caries cavity may not be as conservative as expected, resulting in pulpal exposure which may be either strictly iatrogenic (mechanical exposure of pulp tissue after caries removal) or caused by the severity of the dental caries *per se*.

Initial clinical and radiographic examination is essential in order to avoid possible pulpal exposure during the management of deep cavities. The presence of spontaneous pain, tenderness to thermal stimuli, or painful occlusal contact may indicate the extent of pulpal inflammation, although a complete absence of symptoms in the presence of profound damage is often more worrying. In such cases, the two possible diagnoses include pulpal necrosis or asymptomatic irreversible pulpitis. In case of necrosis, the patient must be informed immediately and a complete

Table. Evidence for the management of non-cavitated and cavitated dentine lesions carried out in LACC.

Type of intervention	Strategies	Study/ Country	Type of study/ Scenario	Lesion severity and dentition	Outcomes	LACC/local barriers for discussion
Micro-invasive x non-invasive	Resin infiltration × proximal sealing × placebo	Martignon et al.[65], 2012/ Colombia	RCT/University clinic	Non-cavitated proximal lesions	Proportion of caries progression was 32% from the infiltrated, 41% from the sealed, and 70% from the placebo over 3 years follow-up. Infiltration and sealing were significantly more efficacious than placebo. No significant difference was observed between infiltration and sealing	Careful selection of cases as well as periodical radiographic and clinical examination is encouraged Depend on availability of x-rays Data on the cost-effectiveness of resin infiltration in comparison with other treatment options are still scarce
	Resin infiltration + dental floss × dental floss	Jorge et al.[66], 2019/Brazil	RCT/University clinic	Non-cavitated proximal lesions	Caries progression was observed in 24.1% of the test lesions compared with 55.2% of the control lesions (p = 0.012) over 24 months follow-up	
	Resin infiltration × no infiltration	Sarti et al.[67,] 2020/Brazil	RCT/University clinic	Non-cavitated proximal lesions	Caries progression was observed in 54.1% of the test lesions compared with 79.2% of the control lesions (p = 0.03)	
Micro-invasive x restorative	Resin sealant without carious tissue removal × SRFD + composite resin restoration	Hesse et al.[45], 2014/Brazil	RCT/University clinic	Occlusal cavitated dentine lesions on primary molars	Both strategies had similar efficacy in terms of lesion arrestment (100%) over 18 months follow-up. Lower longevity of resin sealant due to partial or total loss over the studied period was reported	Need of regular review visits for repairing/resealing the resin sealants restorations
	Resin sealant without carious tissue removal × NSRHD + composite resin restoration	Alves et al.[48], 2017/Brazil	RCT/University clinic	Occlusal cavitated dentine lesions on permanent posterior teeth	Both strategies had similar efficacy in terms of lesion arrestment (94% for sealant and 100% for composite resin) over 3-4years follow-up Success rate in terms of restoration longevity was lower for sealants (76%) than for composite resin (94%) Deposition of tertiary dentine deposition was found in both groups	Need of regular review visits for repairing/resealing the resin sealants restorations
	Flowable resin without carious tissue removal × SRFD + composite resin restoration	Dias et al.[46], 2018/Brazil	RCT/University clinic	Occlusal cavitated dentine lesions on primary molars	Lesion progression over 24 months follow-up period and similar between flowable resin (3.7%) and SRFD (4.8%). Similar success rate in terms of restoration longevity was observed	
Minimally invasive x restorative	ART (two types of GIC): Ketac-Molar × Vidrion	Menezes et al.[64], 2006/ Brazil	RCT/University clinic	Single- and multiple surface cavitated dentine lesions on primary molars	Ketac-Molar restorations involving 1 surface (occlusal) presented the best outcomes over 12-months follow-up	
	ART (HV-GIC × RM-GIC)	Cefaly et al.[68], 2007/ Brazil	RCT/Suburban public schools	Multiple surfaces cavitated dentine lesions on permanent molars	Survival rate of both HV-GIC (93%) and RM-GIC (100%) were similar over 12-months follow-up	

Continue...

Table. Continuation.

Type of intervention	Strategies	Study/ Country	Type of study/ Scenario	Lesion severity and dentition	Outcomes	LACC/local barriers for discussion
Minimally invasive x restorative	ART (HV-GIC × ZOE cement)	Zanatta et al.[69], 2011/ Brazil	RCT/ Public health centers	Single- and multiple surfaces cavitated dentine lesions on posterior permanent molars	The survival rate of single-surface (86.5%) was higher than multiple (57.6%) surfaces over 10 years follow-up. About 90.8% of ZOE cement restorations failed after 2 years	
	ART (HV-GIC) × NSRHD (amalgam restoration)	Mijan et al.[22], 2014/Brazil	RCT/Public primary schools	Occlusal and occlusoproximal Cavitated dentine lesions on primary molars	Cumulative survival rates (up to 90%) over 3.5 years follow-up was similar between NSRHD and ART	
	ART (HV-GIC) × NSRHD (amalgam restoration)	Hilgert et al.[70], 2014/ Brazil	RCT/Public primary schools	Single- and multiple surfaces cavitated dentine lesions on primary teeth	Cumulative survival rate of amalgam restorations over 3 years follow-up for single and multiple surfaces (93.4% and 64.7%) were similar to HV-GIC (90.1% and 56.4%)	
	ART (HV-GIC) × NSRHD (composite resin restoration)	Molina et al.[71], 2018/ Argentina	RCT/ Special care service for patients with intellectual disability	Cavitated dentine lesions on primary and/or permanent dentitions	The cumulative success rate of all ART (94.8%) was higher than all resin composite restorations (82.3%) over 3-years follow up. For both treatments, cumulative success rate was higher for single surface restorations	
	30% silver diamine fluoride × ART	Vollú et al.[72], 2019/Brazil	RCT/University clinic	Occlusal cavitated dentin lesions on primary molars	Lesion was considered arrested in 89% of the SDF and 96% of the ART with no significant difference	Shorter chair time and lower cost in favor of SDF
	ART (HV-GIC × low-cost GIC)	Moura et al.[51], 2020/ Brazil	RCT/Daycare centers	Single- and multiple-surfaces cavitated dentine lesions on anterior or posterior primary teeth	Restorations performed with HV-GIC were more successful over 12-months follow-up	Success is directly related to the quality of the restorative material/Low-cost materials present bad survival
	ART (HV-GIC × two brands of low-cost GIC)	Olegário et al.[52], 2020/ Brazil	RCT/Public schools	Occlusal cavitated dentine lesions on primary molars	Survival rate of HV-GIC was higher (72.7%) than for the other low-cost GIC (46.5 and 39.6%) over 2 years follow-up	Success is directly related to the quality of the restorative material/Low-cost materials present bad survival
	SRSD + restoration (composite resin) × NSRHD (composite resin restoration)	Ribeiro et al.[73], 1999/ Brazil	RCT/University based	Occlusal and occlusoproximal cavitated dentine lesion on primary molars	No restorative failures were found over 12 months of follow-up	

Continue...

Table. Continuation.

Type of intervention	Strategies	Study/ Country	Type of study/ Scenario	Lesion severity and dentition	Outcomes	LACC/local barriers for discussion
Minimally invasive x restorative	SRFD (leathery) + restoration (composite resin) × NSRHD (composite resin restoration)	Franzon et al.[53], 2014, 2015/Brazil	RCT/University clinic based	Occlusal and occlusoproximal cavitated dentine lesion on primary molars	Success rate (clinical and radiographic) for SRFD (92%) was similar to NSRHD (96%) over 2 years of follow-up More pulp exposure after NSRHD (27.5%) than after SRFD (2%) Lower operative time for SRFD Restoration survival for SRFD (66%) was lower compared with NSRHD (86%) Considering both pulp exposure and restoration failure as outcomes, no differences were found between SRFD (64%) and NSRHD (61%)	Restorations placed after SRFD on primary teeth need to be followed over time
	SRFD (leathery) + restoration (composite resin or RM-GIC) × NSRHD + restoration (composite resin or RM-GIC)	Casagrande et al.[58], 2017/Brazil	Retrospective/ clinical records of University clinic	Single- and multiple surface cavitated dentine lesions on young permanent molars	The overall survival rate of restorations was 57.9% over 3-years Annual failure rate for SRFD (17.3%) and for NSRHD (13.1%) Longevity of restorations was similar for both treatments More pulp exposure was found after NSRHD; More failures for multiple-surface restorations and lower survival rates for RM-GIC than for composite resins; presence of gingival bleeding (≥20%) was a risk for restorative failure	-
	SRSD + restoration (amalgam or composite resin) × SW + restoration (amalgam or composite resin)	Maltz et al.[56], 2012, 2013, 2018/Brazil; Jardim et al.[59], 2020/ Brazil	Multicenter RCT/University and public health services	Single- and multiple surface cavitated dentine lesions on permanent molars	Success rate in terms of pulp vitality was higher for SRSD compared with SW over the following times: 18 months: SRSD (99%) × SW (86%) 3 years: SRSD (91%) × SW $^{\text{all treatments}}$ (69%) 5 years: SRSD (80%) × SW $^{\text{all treatments}}$ (56%) No pulp exposure was found after SRSD Authors reported that success of SW is highly dependent on completion of the treatment. Different success rates were observed between completed and uncompleted SW: 3 years: 88% (complete); 13% (incomplete) 5 years: 75% (complete); 5% (incomplete) Success rate in terms of restoration longevity was similar between SRSD (79%) and SW (76%) for all restorations over 5-years of follow-up. Similar success was found for amalgam (83%) and composite resins (75%) performed similarly irrespective to the treatment The time taken to perform SRSD was about 39% lower compared with SW	-

LACC: Latin American and Caribbean countries; RCT: randomized controlled trial; NSRHD: non-selective removal to hard dentine; SRSD: selective removal of carious tissue to soft dentin; SRFD: selective removal of carious tissue to firm/leathery dentine; ART: atraumatic restorative treatment; HV-GIC: high-viscosity glass ionomer cement; RM-GIC: resin-modified glass ionomer cement; ZOE: zinc oxide eugenol; SW: stepwise excavation.

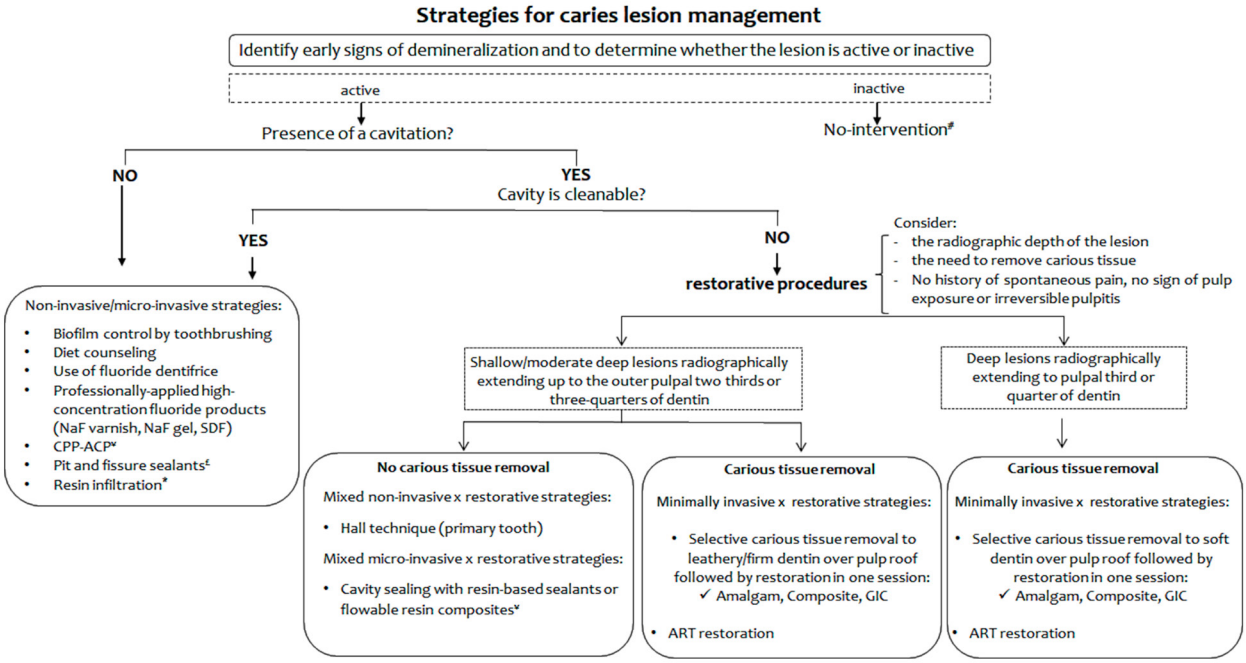

Figure 1. Decision-making flowchart for the management of non-cavitated and cavitated lesions adapted to the LACC context. NaF: sodium fluoride; SDF: silver diamine fluoride solution; CPP-ACP: casein phosphopeptide-amorphous calcium phosphate; ART restoration: Atraumatic restorative treatment; ¥More evidence from clinical studies are necessary; £For non-cavitated lesions or cavitated lesions restricted to the enamel. Dentinal involvement of occlusal lesions must be assessed using bitewing radiographs; *For non-cavitated lesions only; #except for inactive cavitated lesions requiring protection of the pulp–dentin complex and recovery of the tooth´s function, form, and aesthetics.

invasive root canal treatment must be conducted prior to placement of a restoration.

Once pulp vitality is confirmed and possible pulpal compromise is recognized, the clinician must try to preserve the pulpal health status as much as possible. Selective removal of caries tissues in deep caries lesions may result in *i*) close proximity to the pulp tissue, *ii*) direct exposure of the superficial dental pulp, or *iii*) deeper pulpal involvement. The most common treatment measure for the first scenario often adopted in LACCs involves the use of liners or base materials (indirect pulp capping) such as calcium hydroxide pastes or glass-ionomer cements followed by direct restoration using bioactive composites.[74] However, recent studies have questioned the benefits of calcium hydroxide liners, and have suggested that a possible overestimation of their clinical benefits may have occurred.[41,75,76,77]

Exposure of the superficial pulp will require manipulation of the tissue and different kinds of vital pulp treatment (VPT), including direct pulp capping and partial or complete pulpotomies using bio-ceramic materials. Direct pulp capping is typically recommended for class I (no prior presence of a deep caries lesion; pulp exposure surrounded by sound dentine; expectation that the underlying pulp tissue is healthy) or class II (preoperative presence of a deep caries lesion; pulp exposure judged to have occurred in a zone of bacterial contamination; expectation that the underlying pulp tissue is inflamed) lesions[78] and is preferred over complete root canal treatment. However, its feasibility depends on local clinical findings such as adequate bleeding control and extension of the exposure. Hemostasis and disinfection can be successfully achieved by cleaning the wound with sodium hypochlorite, although other irrigating solutions such as chlorhexidine may also be used.[4] Although this intervention is typically recommended for permanent dentition, recent evidence also supports its use in primary teeth with promising results.[79] Although calcium hydroxide is the most commonly used material for VPT, the introduction of calcium

silicate-based cements such as mineral trioxide aggregate (MTA) and tricalcium silicate cement (Biodentine) increases possibilities with regard to clinical performance. A recent clinical trial that compared calcium hydroxide, MTA, and Biodentine for direct pulp capping demonstrated similar clinical outcomes for all three materials, with calcium silicate offering certain clinical advantages such as improved manipulation and acceptable setting time.[80]

Circumstances where the inflammation process has spread beyond the pulp exposure and the bleeding is not reddish on clinical observation, conventional root canal treatment and further restoration may be the treatment of choice. This is a popular treatment procedure as it provides positive outcomes and allows immediate control of the patient's symptoms. However, recently introduced treatment alternatives with promising outcomes include a mid-step treatment involving partial or complete pulpotomy instead of a complete root canal for permanent teeth.[81] Although pulpotomies are frequently used in primary teeth, the application of calcium/silicate cement offers a suitable alternative for the treatment of deep caries lesions with exposed pulp. Interestingly, a systematic review comparing partial/full pulpotomies with direct pulp capping in permanent teeth showed that the former provided more predictable outcomes.[82] Specifically, partial pulpotomies were seen to exhibit high success rates in exposed caries permanent molars up to 2 years post-operatively.[83] Recent evidence shows that full pulpotomies obturated with Biodentine resulted in immediate pain relief and presented excellent clinical and radiographic outcomes after one year, even in cases previously diagnosed with symptomatic irreversible pulpitis.[84] Figure 2 shows a decision-making diagram for pulp protection and the management of exposed pulp in deep caries lesions in the context of LACCs.

There are a wide range of treatment options for pulp protection and the management of exposed pulp; however, some of these options remain controversial and their success depends on the practitioner's clinical skills as well as the availability of modern equipment and bioactive materials (often limited in LACCs). Greater global efforts and further research are essential in order to improve access to the most current technologies and achieve standardization of treatment options for both primary and permanent teeth.

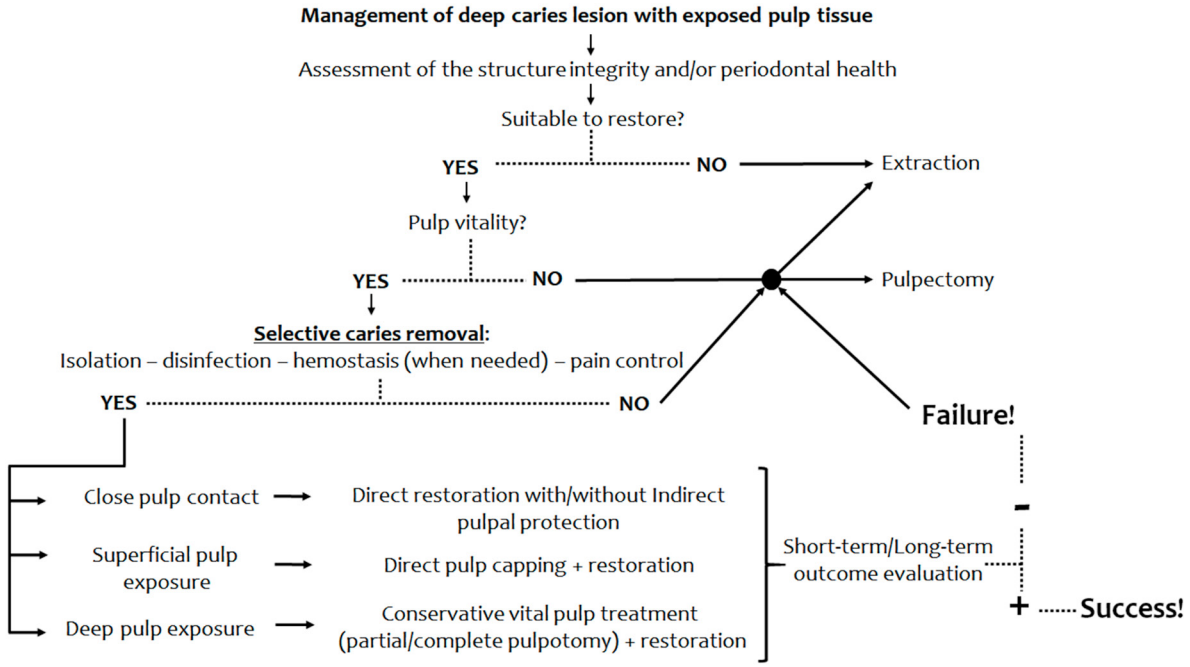

Figure 2. Decision-making flowchart for treatment of deep caries lesions compromising the dental pulp. Strategies for the treatment of primary dentition must be adapted to the patient's age, their orthodontic and exfoliation status, and the risk of affection of the subjacent permanent teeth.

Social perspectives and challenges of caries lesion management in LACC

Accurate diagnosis of caries lesion activity and extension is crucial for selection of the best management strategy. Caries lesions can be appropriately managed and tooth functionality can be preserved long-term with the help of less invasive strategies that take caries biology as well as the individual patient's socioeconomic circumstances into consideration. LACC clinicians can restore the health and esthetics of primary or permanent dentition satisfactorily using a range of treatment options, and the implementation of adequate oral care services can help overcome the majority of associated challenges despite limited public resources in these countries. Modern dental academics institutions and clinical practitioners are encouraged to reshape their approach to caries lesion management by adopting evidence-based practice, and prioritization of cost effective, feasible, less invasive, and safer strategies that are well-supported by published evidence is essential. The knowledge and application of these management approaches may help address persisting barriers to change and minimize the unnecessary use of more invasive interventions.

Although the prevalence of dental caries in permanent teeth among adolescents is decreasing in LACCs,[85] it remains a relevant public health problem as more than half of the population of 12-year-old adolescents exhibit one or more cavitated caries lesions. No significant decrease in caries prevalence has been observed among primary teeth since the year 2000, and efforts to control the disease should be focused on lower socioeconomic strata that exhibit the highest prevalence.[85] These strategies must be cost effective and based on reliable evidence.

Assessment of the cost-effectiveness of any strategy aimed at the management of untreated caries lesions, which are increasingly prevalent among high-risk populations, is essential in order to reduce the financial burden in LACCs. These should be evidence-based and range from early preventive interventions to the management of non-cavitated and cavitated caries lesions. With regard to community-based strategies, programs such as water and salt fluoridation have been shown to be economically beneficial, with DMFT scores decreasing drastically in the Chilean population after 6 years of program implementation.[86] Moreover, both water and salt fluoridation were also reported to be cost effective, with the latter being slightly superior to the former.

Strategies that combine biological approaches with the best preventive practice (B+P; based on either non-caries tissue removal or selective caries tissue removal followed by restoration) for the management of caries lesions in the primary dentition have been found to be the most cost effective in studies conducted in developed countries.[87] Although clinical trials using similar approaches have been conducted in deprived communities in LACCs,[22] evidence on their cost-effectiveness is still scarce. Conversely, controversial results regarding the cost-effectiveness of preventive measures for first permanent molars have shown some dependency on the application of fluoride varnishes and pit and fissure sealants.[88,89] Regardless of the strategy, any of these resources should be advisable for high-risk patients.

The best strategies for the management of dental caries, a multifactorial disease, address a range of issues instead of focusing on isolated management options only. Therefore, structured preventive programs such as CMS (Caries Management System: based on regular monitoring and non-invasive management for the control of lesion progression and promotion of re-mineralization in non-cavitated lesions);[90] BPOC (Basic Package of Oral Care that is recommended for deprived communities and is based on ART and widespread use of affordable fluoride dentifrices);[91] B+P;[87] OHPP[92] (Oral-Health Promotion Program: based on screening children's teeth, supervised tooth-brushing with fluoride dentifrices, and dietary control); Hall technique; and ART[43,93,94] have been shown to be the most cost-effective tools for provision of optimal oral-health care and management of caries lesions. Therefore, the implementation of tailored and individual oral healthcare packages would be a desirable approach for LACCs considering the sociodemographic characteristics of this region.

The findings of this review showed selective caries tissue removal limited to softened dentin

over the pulpal roof was the most cost-effective strategy for the management of deep caries lesions, particularly in high-risk individuals.[95,96] However, it may take some time for professionals in LACCs to accept and incorporate such changes, with one study showing that older dentists in public services in southern Brazil were more likely to choose strategies with higher risk of pulp compromise or poorer prognosis for the management of deep caries lesions when compared to their younger colleagues, possibly because the latter had been educated in a more conservative manner.[97]

In case of root caries lesions, mechanical removal of dental biofilm with the help of 5000 ppm F dentifrices has been shown to exhibit high efficacy in older adults.[23] SDF is also considered to be an excellent cost-effective resource in case of such lesions,[98] although there are currently no standardized guidelines for its effective use in arresting dentin lesions in primary and permanent dentition.

From the perspective of oral-health practitioners in LACCs as well as educational institutions and national dental associations in the region, what are the specific actions for the management of dental caries and dental caries lesions in this geographic region? Firstly, continuing education through regular updates of clinical training is a crucial part of our responsibility to promote change in the profession and curriculum. Secondly, reviewing and adapting programs that emphasize preventive tasks, improve public oral health, promote the use of materials and techniques adapted to the personal needs of the patients, and favor evidence-based dentistry is essential. Therefore, dental education and practice as a whole must be adapted to the current reality of LACCs.

Oral-health care systems differ in structure and scope around the world and also within LACCs, and these differences are influenced by various economic and political factors. Despite the efforts of many countries to build national policies that make primary health care accessible to the whole population; this goal has not been achieved in most LACCs as yet. Proper social and health data about the prevalence and severity of dental caries, which are essential for health policy-makers, are still not available in all countries.[99] Decisions on how to manage and control caries lesions should be guided by clinical protocols based on the available evidence on effectiveness as well as a comprehensive understanding of the local oral-health scenario and available resources.[100] Strategies should be effective, affordable, and should contribute to providing equity in access to oral-health services. Assessment of the cost-effectiveness of caries management strategies should take into consideration initial treatment costs as well as those associated with success/failure rates and the possible need for retreatment.

Conclusions

a. Individualized treatment based on the risk management,[101] of the disease process and on the control of the caries lesion activity/development is important for adequate and effective condition control.
b. Daily use of fluoride dentifrices (1000-1500 ppm F) is highly recommended as a preventive and therapeutic strategy for the management of dental caries lesions. Some studies have recommended use of fluoride dentifrices at concentrations of 5000 ppm or SDF for the management of root caries. Pit and fissure sealants as well as resin infiltrants may be used for the management of non-cavitated lesions.
c. Restorative treatments that focus on filling cavities only without controlling the disease are not beneficial. Individuals should always be motivated and encouraged to improve their oral hygiene and acquire healthy dietary habits.[14]
d. Restorative treatments allowing maximum preservation of tooth structure should be indicated whenever lesion progression cannot be arrested by non-invasive/micro-invasive interventions,[11] such as in the case of active cavitated lesions that cannot be cleaned. The Hall technique is recommended as a mixed non-invasive and restorative strategy for primary molars.[42,43,44,102] Selective removal of caries tissues over the pulp chamber roof (up to leathery/firm dentin in case of shallow/

moderate deep lesions or to soft dentin in case of deep lesions) should be carried out when necessary.[11]

e. Selective removal of caries tissues up to soft dentin over the pulp chamber roof followed by definitive restoration in one session must be the recommended treatment of choice for symptomless deep caries lesions.[11,53,56,57,58,59]

f. ART restorations exhibit higher survival rates over time, especially for single-surface restorations, in both primary and permanent teeth. This method may be considered as a feasible strategy for places without a proper clinical set-up or at public health systems/ private practices with budget restrictions. However, the use of high-quality standardized materials is necessary to ensure restoration longevity.[22,50,51,52,64,68,69,70,71,72]

g. There is limited evidence in support of the direct placement of restorative materials over evident cavitated lesions (shallow to moderate depth) without prior caries tissue removal in LACCs,[45,46,48] and further well-designed studies are necessary in order for a definitive recommendation to be made.

h. Invasive restorative treatments should be postponed in favor of restoration repair whenever possible. Moreover, replacement of restorations should be discouraged or only recommended in the absence of other viable options. Shorter intervals between recall visits should be adopted after taking the patient's caries risk and/or activity into consideration to allow repair of any restoration defects in a timely manner.

i. As per the International Association for Dental Research (IADR), dental amalgam continues to present adequate longevity and cost-effectiveness, despite development of new adhesive and aesthetic restorative materials. Therefore, when other restorative materials are less optimal due to clinical, economic, and practical reasons, amalgam should be considered as an acceptable option for the general population provided they do not exhibit any allergies to its constituents or present with severe renal diseases. As per the IADR, currently there is insufficient evidence in support of a causal relationship between mercury from amalgam restorations and adverse systemic health outcomes. Furthermore, the available evidence does not preclude the use of amalgam as a tooth restoration material nor suggest the need for replacement of pre-existing amalgam restorations.[103] However, we do acknowledge that current evidence suggests that both amalgam and resin composites exhibit equal clinical success and that it is fair to state that the philosophy behind amalgam restorations does not comply with the paradigm of Minimally Invasive Dentistry. In this context, amalgam should not be considered as a gold-standard restorative material.

j. Non-invasive vital pulp therapies such as direct and indirect pulp capping have been shown clinical and radiographically to be useful for the treatment of primary and permanent (mature and immature) teeth with deep caries lesions.[74]

k. Pulpotomy procedures have been extensively employed as a routine treatment option e for primary teeth with reversible pulpal inflammation. Moreover, pulpotomies have exhibited high success rates when used for the management of pulp exposure in deep caries lesions in permanent teeth. Therefore, this procedure is currently considered as a suitable substitute for root canal treatment, even in cases diagnosed with irreversible pulpitis, as it offers time, clinical, and cost-effectiveness advantages.[104,105]

l. Despite evidence from randomized controlled trials and systematic reviews, the choice of strategies for caries lesion management at the population level must take into consideration the cost-effectiveness, available financial and technical resources, and the needs of public health systems and private practices. Moreover, there is a lack of pragmatic data confirming whether the evidence provided by randomized controlled trials is reproducible in real settings where dental treatments are delivered by clinicians (such as public health systems and private practices).

Recommendations

a. Let's go back to the basics: Before opting for new alternatives for the treatment of dental caries, consideration of the biological processes of dental caries development will allow the clinician to make treatment decisions with the expected outcome.
b. Consider the sociodemographic context: Various attractive therapeutic options such as novel biomaterials or techniques may be unavailable in some LACCs, and this must be taken into consideration by clinicians when selecting a treatment strategy.
c. Always analyze the individual patient's needs: the target affected population typically belongs to the lower socioeconomic strata in developing LACCs and, therefore, may be unable to access a wide range of treatment options. In such situations, the preservation of public health and assurance of oral-health care provision must supersede any secondary outcomes.
d. The gap between industry, academia, and the clinical sector must be bridged in LACCs: International as well as local industries in LACCs must monitor the clinical outcomes of various treatment options and, where possible, develop new materials to further improve the caries lesion management process. These developments must be carried out in collaboration with academic organizations under strict ethical control, and well-trained clinicians may contribute to the process through the provision of pragmatic information.
e. Generate high-quality scientific and pragmatic evidence: The present manuscript highlights the need for more high-quality scientific evidence adapted to the local geographical region. Moreover, it is also complemented by the recognition of severe deficiencies in the existing oral public health systems of LACCs including inequalities in access to services among the general population, financial limitations of the governments, and lack of standardized clinical guidelines for adequate preventive and restorative treatment of caries lesions adapted to the local geographical and cultural context.
f. Never stop learning: Dental caries management is a dynamic process characterized by the development of new emerging trends replacing dated paradigms. As a result, it is imperative that clinicians equip themselves with the most recent, reliable evidence so as to prepare themselves for the adoption of new treatment alternatives as and when they become locally available.

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Original Research
Cariology

Dental caries prevalence, prospects, and challenges for Latin America and Caribbean countries: a summary and final recommendations from a Regional Consensus

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Abstract: Dental caries can be effectively managed and prevented from developing into cavitated lesions while preserving tooth structure at all levels. However, the strong correlation between caries and socioeconomic factors may compromise the efficacy of preventive strategies. The high prevalence of persistent inequalities in dental caries in Latin American and Caribbean countries (LACC) is a matter of concern. The estimates of the burden of disease in some countries in this region are outdated or absent. This paper aims to summarize and present the final recommendations of a regional Consensus for Dental Caries Prevalence, Prospects, and Challenges for LACC. This consensus is based on four articles that were written by a team of Latin American experts, reviewed by dental associations, and presented and discussed in two consensus events. The following domains were explored: epidemiology, risk factors, prevention strategies, and management of dental caries with a focus on restorative procedures. Dental caries can manifest throughout the lifespan of an individual, making it a matter of concern for infants, children, adults, and older people alike. The prevalence rates of untreated caries in deciduous and permanent teeth are high in many parts of the world, including LACCs. Previous evidence suggests that the prevalence of dental caries in 12-year-olds is moderate to high in most Latin American countries. Moreover, the prevalence of treatment needs and dental caries in the adult and elderly population can also be regarded as high in this region. The risk/protective factors *(e.g.,* sugar consumption, exposure to fluoride, and oral hygiene) probably operate similarly in all LACCs, although variations in the interplay of these factors in some countries and within the same country cannot be ruled out. Although salt and water fluoridation programs are implemented in many countries, there is a need for implementation of a surveillance policy. There is also room for improvement with regard to the introduction of minimal intervention techniques in practice and public health programs. Dental caries is a marker of social disadvantage, and oral health promotion programs and interventions aimed at reducing the burden of dental caries in LACCs must consider the complexity of the socioeconomic dynamics in this region. There is an urgent need to promote engagement of stakeholders, policymakers, medical personnel, universities, dental

associations, community members, and industries to develop regional plans that enhance the oral health agenda for LACCs. A list of recommendations has been presented to underpin strategies aimed at reducing the prevalence and severity of dental caries and improving the quality of life of the impacted LACC population in the near future.

Keywords: Dental Caries; Epidemiology; Policy Making; Latin America; Caribbean Region.

Introduction

Our understanding of the interplay between the initiation and progression of carious lesions in deciduous and permanent teeth and the associated risk and protective factors has improved considerably over the past few decades. As previously reported, dental caries is a biofilm-mediated, multifactorial, dynamic disease driven by increased sugar consumption and characterized by phasic demineralization and remineralization of dental hard tissues.[1,2] It currently represents a major public health problem globally despite a steady decline in prevalence rates in several countries; extensive, well-designed research; and increased comprehension of its pathology and management.[3,4]

Untreated carious lesions of permanent teeth were the most prevalent health condition in 2010, affecting >2 billion people (approximately 35% of the population) globally whereas carious lesions of deciduous teeth were the 10th most prevalent condition, affecting 9% of the global population.[3] The Global Burden of Diseases Study recently estimated that the prevalence rates of untreated dental caries decreased by only 4% globally in the last decade, suggesting that the marked decline observed over the past 30 years was slowing down. Moreover, the relative stability of these global numbers raises questions about the reduction of prevalence over the past 30 years.[4,5,6]

The first paper published from this consensus focused on the burden of dental caries in Latin American and Caribbean countries (LACC), particularly in socioeconomically deprived populations as dental caries often acts as a marker of social disadvantage, and its effect on the quality of life of the Latin American and Caribbean population. The second article[7] of this consensus explored our understanding of the mechanisms by which risk factors operate in great detail, as much of the available epidemiological evidence from LACCs is inconsistent.[1] Lastly, a lack of robust epidemiological evidence on dental caries can seriously jeopardize the ability to develop effective preventive and restorative strategies for the control of dental caries, and these key themes have been discussed further in articles 3 and 4 of this consensus.[8,9]

Like much of the developing world, some of the key challenges faced by LACCs include persistent inequality, poverty, high levels of corruption, and over-burdened public healthcare systems. This is further aggravated by a recent unprecedented migration crisis in Venezuela and Central America, creating a complex inhospitable scenario that complicates management of this multidimensional disease. Promoting engagement with stakeholders, policymakers, medical personnel, universities, dental associations, community members, and industries will allow development of tailored regional plans and enhancement of the oral health agenda. Cariologists, epidemiologists, and researchers must share best practice measures for effective management of dental caries as well as successful innovative approaches used to reduce the prevalence and severity of dental caries, taking regional challenges into consideration.

The current consensus contributes to this discussion and, most importantly, attempts to highlight the fact that dental caries is a preventable disease. There is sufficient available evidence on the prevention and control of this disease, even in deprived communities such as those in LACCs. Therefore, the aim of this paper is to present and summarize the final recommendations of the Latin American Consensus, "Dental Caries Prevalence, Prospects and Challenges for Latin American and Caribbean countries".

Latin America in numbers

The LACC region includes 33 countries with 650 million inhabitants who speak a Romance language (derived from Vulgar Latin). Fifteen autonomous territories or Areas of Special Sovereignty (USA, UK, and The Netherlands) have been included in many statistical surveys conducted within this geographical region.[10,11,12]

The LACC region represents 9% of the global population, with projections estimating approximately 730 million inhabitants by 2050.[10] It is the fourth most populated region in the world, with a predominantly urban population as a result of high urbanization rates (82.5%) comparable to that of the developed world. However, in contrast to wealthy urbanized countries, LACCs face several challenges such as structural constraints on the economy, under-funded and over-burdened public healthcare systems, and perhaps most importantly, persistently high levels of social inequality.[13] In fact, various political and anthropological analyses have concluded that, despite economic reforms and social progress in some areas over the past few decades, the fundamental tenets of socioeconomic inequalities have not been substantially challenged in the region as yet.[14]

The current prevalence rates of oral health treatments and dental caries in the LACC region is worrying despite steady declines in the rates of caries in permanent teeth as observed in countries such as Brazil, Mexico, and Colombia. Moreover, the prevalence of dental caries in the primary dentition continues to remain high in the majority of LACCs, with > 50% of children and > 85% of the adult population being affected.[1,6] A recent study showed that only five countries (Brazil, Colombia, Panama, Chile, and Uruguay) in the region had implemented oral health surveys of nationally representative samples of adults between 2000 and 2015.[15] In 2018, Mexico published a national survey summarizing the status of dental caries in 32 federative entities in the country, with samples being collected from individuals belonging to different age groups over a period of two decades.[16]

The lack of epidemiological data in LACCs suggests that health planning in the region is largely based on considerable levels of uncertainty. Therefore, Edgar Morin's advice, "*we should learn to navigate on a sea of uncertainties, sailing in and around islands of certainty,*" appears particularly relevant when planning regional oral health strategies taking uncertainties in educational issues in LACCs into consideration.[17]

Rural areas are typically faced with remarkable social challenges, requiring the development of audacious initiatives that deliver effective evidence-based care to the population. Currently, it is estimated that more than 400 different indigenous groups live in the LACC region, the majority of which are found in Bolivia, Guatemala, Peru, Ecuador, and Mexico.[18] Therefore, oral health promotion programs should take into consideration the specificities and cultural characteristics of these communities as their participation is crucial for success.

It is also important to observe how rural populations and vulnerable urban communities understand oral health, as low literacy rates can delay caries detection, hinder adherence to preventive strategies, and jeopardize well-designed oral health promotion programs.[19,20] Increased community involvement and research approaches that cater to traditionally excluded and marginalized sections of the society are essential, particularly in the context of the extensive internal and cross-national migration crisis being observed in Latin America. This displacement crisis is motivated by a number of reasons, including political and economic factors, security issues, natural disasters, and development projects (*e.g.*, mining concessions).[10,11] Humanitarian operations being carried out in the border areas will soon prove to be inadequate for the provision of good health conditions to the migrants, and a combined regional and national response must be organized, particularly in countries such as Colombia and Mexico where the public healthcare systems are already overburdened and the number of refugees and migrants is escalating steadily.

Public health approaches used to reduce the burden of dental caries in LACCs must tackle the "causes of the causes" by addressing the historical and cultural aspects of the disease burden in addition to its social determinants. LACCs have a strong historical link to the production and consumption of sugar, accounting for approximately 40% of the global sugar output,

and this is expected to remain stable until 2028.[21] The global consumption of sugar is increasing and has doubled (from 80 to 160 million tons/year) since the late 1970s. The LACC region too has exhibited a rising trend in consumption, despite numerous campaigns aimed at reducing intake. In 2015, a global analysis of the estimated daily calorie intake from sweetened sugar beverages per capita found that Chile, Mexico, Argentina, and Brazil exhibited the highest rates in the LACC region,[22] and this could partly be attributed to strong opposition by the sugar industry to anti-obesity regulations such as soda taxes and front-of-package nutrition labeling.[23] According to the International Diabetes Federation, more than 26 million inhabitants of Latin America are expected to develop type 2 diabetes by 2025[24] representing an 85% increase in the prevalence rates. Estimating the prevalence of dental caries between the years 2025 and 2030 based on general trends from the LACC region showed that this region is undergoing a transition in development. The complexity of the social and economic environment in the region highlights the need for international efforts to advance regional plans for controlling dental caries.

Trends of and risk factors for dental caries in LACCs: summary of articles 1 and 2 of this Consensus

There is limited epidemiological evidence on the prevalence of dental caries in children and adults in LACCs, and although reliable national data is available for a few countries, the remainder either do not have any epidemiological evidence on prevalence rates or rely on small-scale studies for the same.[15] Moreover, much of this evidence may be outdated despite being representative and significant. Although the guidelines proposed by the World Health Organization (WHO) have been available since the 1970s, there is a lack of standardization in dental epidemiological studies. Furthermore, many countries have not established a standardized database and system to monitor changes in dental caries prevalence rates.[1]

Article 1 of this consensus[1] showed the existence of a wide range in reported mean DMFT scores of 12-year-old children, and recent evidence suitable for appropriate interpretation and regional comparisons is only available in a few countries. Till date, only two systematic reviews conducted in 1970 and 2016 have examined caries trends in 12-year-old children in the LACC region, making it difficult to ascertain whether the disease burden is increasing or decreasing in this region.[6,25]

A few studies examining 12-year-old children in LACCs showed that the symptoms of dental caries and associated functional alterations often led to psychological issues that negatively affected the oral health-related quality of life of the LACC population. Moreover, these effects generally presented as a cumulative experience that worsened with disease progression, with severe cases impeding the patient's daily activities as well as that of their family members.[1]

Caries risk assessment comprises of a range of factors that are not stable and also interact with one another, and a few epidemiological surveys in LACCs investigating some of the main risk factors of dental caries have corroborated the findings of previous systematic reviews.[7] Non-white ethnicity, low educational levels exhibited by the parents, low family income, availability of a health insurance scheme, and old age have been associated with higher dental caries prevalence in the LACC population.[26] Additionally, behavioral risk factors such as a cariogenic diet, high frequency of sugar intake, additional sugar consumption, and poor oral hygiene have also been associated with increased risk of dental caries in this population. Other studies carried out in the LACC population demonstrated that the saliva buffering capacity, presence of *S. mutans* in the saliva, presence of erupting primary and permanent molars, and enamel defects were also related to the prevalence of dental caries.[7]

Previous studies have reported that the key risk factors of dental caries can occur at various stages of life. In older people, some factors that indicate a higher risk of caries include exposed root surfaces, increased root caries, gingival recession, poor oral hygiene, and lower socioeconomic levels. However, these findings have not been investigated in the LACC population.[7]

Potential strategies for preventing and controlling dental caries: summary of articles 3 and 4

Individual and context-driven healthy behaviors such as controlled sugar consumption and regular contact with fluorides are regarded as effective ways to prevent dental caries across all ages. Two additional strategies, application of dental sealants and oral health education, may also be implemented in order to achieve this objective[8]. However, synergistic implementation of these strategies is essential for effective caries control in the long term.

The LACC region is a powerhouse of the global sugar industry, with sugar plantations forming a major part of the local economy. Approximately half of the sugar produced in the region is destined for domestic consumption whereas the remainder is exported. Global sugar consumption is increasing, lowering associated costs and making it more widely available. In 2018, the average per capita consumption of sugar was 39.9 kilos/year in Central America and the Caribbean, 41.8 kilos/year in South America, and 34.7 kilos/year in Mexico. These values are considerably higher than those observed in Asia (18.2 kilos/year) and Africa (15.3 kilos/year), highlighting the need for population-based strategies aimed at reducing and controlling sugar intake to manage the risk of non-communicable diseases such as dental caries in LACCs. However, implementation of such strategies will be challenging due to the high rates of sugar consumption in the LACC region, and will be further complicated by limited available evidence on the efficacy of such strategies in this region.[7]

Although community-level fluoridation programs (such as fluoridated water or salt) are widespread in LACCs,[8] the strategy is limited by several factors such as discrepancies in the areas covered within a country, unequal access to its benefits, and the need for efficient surveillance systems to monitor fluoride concentrations. This has led to discontinuation of the strategy in some regions. The use of fluoridated milk has also been reported,[8] although less frequently compared to water and salt. Fluoride dentifrices, a popular individual-level strategy for caries control, may be more effective in its reach compared to community approaches in areas not covered by water or salt fluoridation. However, adequate provision of information on the frequency of use of fluoride dentifrices and the release of soluble fluorides from the formulation into the mouth during tooth brushing is necessary in order to achieve an anti-caries effect.[27] Unfortunately, the majority of the population remains unaware of this information, making selection of appropriate commercially available fluoridated dentifrices difficult, particularly in the context of easily available poor-quality formulations with insufficient fluoride concentrations resulting in questionable anti-caries effects. On the other hand, incorporation of additives in fluoride toothpastes (*e.g.*, arginine) has shown promising results as these new technologies can enhance the effects of fluoride. Therefore, strategies targeting increased accessibility and affordability of high-quality formulations may guarantee the regular use of fluoride toothpastes in this region.

While some LACCs have clear policies on fluoride use,[8] others do not, and proper regional legislations addressing soluble fluoride content in dentifrices along with effective surveillance programs monitoring different sources of fluoride exposure are necessary.[8]

The benefits of using of pit and fissure sealants in permanent teeth is well-established; however, there is limited evidence on its efficacy in primary molars.[8] Several systematic reviews have reported substantial effectiveness of sealants in the prevention and control of occlusal caries when compared to no intervention although this may have been affected by the incidence of caries in the population. Community-based strategies promoting the use of occlusal sealants are scarce in the LACC region.

Educational interventions carried out by health professionals have the potential to promote good oral health at the individual and community levels.[28] The strong influence of social and behavioral risk factors on the incidence of dental caries highlights the importance of educational interventions targeting sugar consumption, regular contact with fluorides, issues for the appropriation of self-knowledge about the health-disease process, stimulating the autonomy and change in health behaviors leading to prevention and oral health promotion.

The management of a caries lesion is particularly challenging in the LACC region as many countries lack sufficient public health services and equitable access to their benefits.[9] While improving access to benefits is desirable the primary goal is not just the restoration of a single lesion but the stabilization of the general oral function.

Another challenging aspect of caries lesion management is the selection of appropriate treatment measures, which vary with the stage of the lesion, its localization, and activity. The positive aspect is that most of the options are based on minimal intervention techniques.[29] Unfortunately, there is limited evidence on the most commonly used caries management strategies in the LACC region.[9] While frequent use of a fluoridated toothpaste and restricted sugar intake may suffice for initial caries without cavity formation (ICDAS1&2), professional fluoride application (varnish, gel, or mousse) is recommended for high-risk patients. Silver Diamine Fluoride (SDF) may be used for surfaces where esthetics are not mandatory whereas glass ionomer cement or resin sealants can be used on occlusal surfaces.[30,31,32]

Moderate caries may extend into the dentine (ICDAS 3&4), and lesions with localized enamel breakdown may be treated using sealants or SDF on occlusal surfaces. SDF has been shown to be an effective treatment option for caries control on any tooth surface in the primary dentition,[33,34] although there is limited evidence of its efficacy in permanent teeth.[35] Buccal lesions can be controlled using a combination of fluoridated toothpastes, restricted sugar intake, and professional fluoride application. However, in case of no enamel breakdown but presence of an underlying dark shadow in the dentine, the treatment options are dependent on the extent that the dentine is affected. Dental sealants may be used in case of involvement of the external part of the dentine only, whereas cavity preparation, removal of infected dentine, and restoration using glass ionomer cement or resin is recommended in case of greater dentin involvement. The appropriate treatment option should be selected using an X-ray where possible.

Severe carious lesions (ICDAS 5 & 6), which represent the majority, should be treated using either Atraumatic Restorative Treatment (ART) or the Hall technique if the cavity is too large. However, radical strategies including endodontic approaches or extraction of teeth that cannot be restored continue to be popular in the LACC and the use of preventive strategies must be supported in order to minimize the need for invasive interventions at more advanced stages of caries.[9]

The core curriculum for cariology in Latin American and Caribbean countries

The European Organization for Caries Research (ORCA) and the Association of Dental Education in Europe published the results of the first consensus workshop on the development of a European curriculum in cariology ten years ago.[36] The European Core Curriculum in Cariology (CCC) for undergraduate dental students included five educational domains focusing on basic sciences, concepts of evidence-based dentistry, epidemiology, public health, risk assessment, disease detection, diagnosis, decision-making, preventive therapy, and minimally invasive and advanced surgical treatment measures. The impact of the European CCC is noteworthy as it was further developed after a thorough survey of dental schools across Europe.[37]

The CCC was implemented in universities in Brazil, Colombia, Chile, Venezuela, Dominican Republic, and Puerto Rico.[38-42] A survey on the inclusion of cariology education in Spanish-speaking dental schools in LACCs showed that non-operative caries management strategies were not implemented on a regular basis. Moreover, the majority of schools reported focusing on all of the main topics of cariology except those related to behavioral sciences, microbiology, saliva and systemic diseases, caries risk factors, root caries, erosion, and early caries management strategies.[43] In Brazil (a Portuguese-speaking country with more than 200 dental schools), the proportion of universities that provided a specific discipline of cariology seemed to be higher than those reported in Europe and other Latin American countries.[44] Apart from these initiatives, there is no regional discussion about the CCC in LACC.

It is important to note that cariology is currently not only strictly confined to caries-related aspects

but also includes all problems related to the hard tissues of the teeth.[36,44]

A sustainable, comprehensive cariology curriculum that takes local, regional, and national challenges into consideration may prove useful in supporting future programs aimed at reducing the prevalence of dental caries in LACCs. It is essential to recognize that dental graduates represent future dental practitioners who have the potential to operate as valuable stakeholders and policymakers involved in working toward caries control in the near future.[45] The current COVID-19 pandemic has resulted in the development of a myriad of remote/virtual educational strategies, and a structured agenda based on a CCC in LACCs, which has the potential to boost new initiatives for the control of dental caries, generate opportunities to share successful experiences, and create favorable educational environments using virtual platforms.

Proposal of a dental caries surveillance program for LACC

Previous studies as well as a pan-European Consensus have highlighted the variations in thresholds and systems used for dental caries detection and recording.[7,46] An individual's dental caries experience, fluoride exposure, and sugar intake may change over their lifetime, making epidemiological data representative of different age groups essential for the development of effective oral health promotion programs and strategies that can be used to monitor the prevalence and severity of the disease.

As mentioned previously, there is a need for high-quality studies that provide a clear picture of the prevalence of dental caries in LACCs and, in order to achieve this at the national level, this consensus proposes a classification of countries according to the following criteria: a) the availability of epidemiological data on dental caries at the national level (*i.e.*, the caries data must be representative of the country [external validity criterion]); b) how up-to-date the data is (less than 10 years old) for valuable interpretation (temporal proximity criterion); and c) ease of availability from representative institutions (*e.g.*, Ministry of Health) or as published official documents (visibility and accessibility criteria).

Based on the above criteria, a dental caries monitoring or surveillance ranking system was proposed for LACCs (Tables 1, 2, and 3), and the countries were classified as follows: Green: if all criteria were fulfilled (Table 1); Yellow: if only one criteria was not fulfilled (Table 2); and Blank (Table 3): if none of the criteria were fulfilled.[47-65]

Table 1 shows that only three countries (Colombia, Mexico, and Paraguay), accounting for only 30% of the LACC population, have recent official national epidemiological survey data on dental caries (mean DMFT < 3.0 in 12-year-old children) available.

Tables 2 and 3 show that 30 countries, comprising 70% of the LACC population, have official data on dental caries that is more than 10 years old, highlighting the need for national epidemiological surveys in the near future. This is a matter of concern, particularly for the 22 countries (Table 3) comprising approximately 130 thousand inhabitants where the national epidemiological data is over 20 years old. Between1986 and 2004, the DMFT scores of 12-year-old children were recorded at the national level in many LACCs in support of the implementation of salt fluoridation programs. However, our findings suggest that no regional systematic surveillance was carried out during implementation of these salt fluoridation

Table 1. Population, density of dentists, and mean DMFT of 12-year-old children in Latin American and Caribbean countries following the surveillance of dental caries via official national surveys since 2011. LAOHA, 2020.

Countries	Population*	Density of dentists 1:10.000 (year)**	Mean DMFT of 12-year-old children (year)	References
Colombia	50,339,443	9.60 (2015)	1.50 (2013)	47
Mexico	127,575,529	1.00 (2016)	2.65 (2018)	16
Paraguay	7,044,636	1.63 (2018)	2.07 (2017)	48
Total/range years	184,959,608	1.00–9.60 (2015–2018)	1.50–2.65 (2013–2018)	-

*World Bank; United Nations Population Division. World Population Prospects: 2019 Revision; **https://www.who.int/gho/health_workforce/dentistry_density/en/; https://sites.usp.br/iberoamericanoralhealth/

programs, and the efficacy of the program in reducing the prevalence of dental caries in the target age groups was not evaluated.[1,8] Reliable and representative data on caries prevalence in older children, adults, and the elderly is also largely absent, warranting further research in this area.

Table 2. Population, density of dentists, and mean DMFT of 12-year-old children in Latin American and Caribbean countries reported following the surveillance of dental caries via official national surveys conducted from 2001 to 2010 (inclusive). LAOHA, 2020.

Countries	Population*	Density of dentists 1:10.000 (year)**	Mean DMFT of 12-year-old children (year)	References
Antigua and Barbuda	97,929	1.67 (1997)	0.90 (2006)	49
Brazil	211,049,527	12.36 (2017)	2.07 (2010)	50
Chile	18,952,038	1.60 (2016)	1.90 (2007)	51
Costa Rica	5,047,561	0.10 (2017)	2.57 (2006)	52
Ecuador	17,373662	3.20 (2016)	1.61 (2010)	53
Guatemala	16,604,026	0.10 (2018)	5.18 (2002)	54
Haiti	11,263,077	0.21 (2018)	0.65 (2005)	55
Panama	4,314,767	2.79 (2016)	3.72 (2008)	56
Peru	32,516,453	1.80 (2016)	3.67 (2001)	57
Trinidad and Tobago	1,399,488	3.59 (2015)	0.61 (2006)	58
Total/range (years)	318,618,528	0.10–12.36 (1997–2018)	0.90–5.18 (2001–2010)	-

*World Bank; United Nations Population Division. World Population Prospects: 2019 Revision; **https://www.who.int/gho/health_workforce/dentistry_density/en/; https://sites.usp.br/iberoamericanoralhealth/

Table 3. Population, density of dentists, and mean DMFT of 12-year-old children in Latin American and Caribbean countries reported following the surveillance of dental caries via official national surveys conducted before 2000 (inclusive). LAOHA, 2020.

Countries	Population*	Density of dentists 1:10.000 (year)**	Mean DMFT of 12-year-old children (year)	References
Argentina	44,938,712	9.19 (2004)	3.40 (1987)	59
Bahamas	393,244	2.58 (2017)	1.56 (2000)	60
Barbados	287,375	3.08 (2017)	4.40 (1983)	61
Belize	397,628	1.54 (2017)	6.00 (1989)	61
Bolivia	11,513,100	2.23 (2016)	4.70 (1995)	62
Cuba	11,333,483	16.60 (2017)	1.62 (1998)	61
Dominica	71,986	0.67 (2017)	2.50 (1990)	63
Dominican Rep.	10,738,958	2.10 (2017)	4.40 (1997)	64
El Salvador	6,486,205	7.64 (2008)	5.10 (1989)	61
Grenada	112,523	1.57 (2017)	5.50 (1991)	61
Guyana	786,552	0.35 (2018)	1.30 (1995)	61
Jamaica	2,961,167	0.90 (2017)	1.10 (1995)	65
Nicaragua	6,624,554	0.40 (2018)	5.90 (1988)	61
Panama	4,314,767	2.79 (2016)	4.20 (1989)	61
Saint Lucia	183,627	2.26 (2014)	2.70 (1961)	61
St. Kitts and Nevis	53,199	3.68 (2015)	5.50 (1979)	61
St. Vicent and Grenadines	110,94	1.19 (2004)	3.20 (1991)	61
Suriname	586,632	0.48 (2009)	4.90 (1978)	61
Uruguay	3,461,734	14.79 (2017)	2.40a(1999)	61
Venezuela	28,515,829	5.48 (2001)	3.60 (1986)	61
Total/range (years)	129,557,448	0.40–16.60 (2001–2018)	1.10–6.00 (2010–2018)	-

*World Bank; United Nations Population Division. World Population Prospects: 2019 Revision; **https://www.who.int/gho/health_workforce/dentistry_density/en/; https://sites.usp.br/iberoamericanoralhealth/; [a]12- and 13-year-old children.

Epidemiological data also shows a very unbalanced distribution of dentists within the LACC region, with some countries (*e.g.*, Guatemala, Costa Rica, Haiti, Nicaragua, Guyana, and Suriname) having very low numbers of professionals per inhabitants and others (Cuba, Brazil, Colombia, Argentina, and Uruguay) exhibiting a moderate or high density of professionals. This suggests a trend toward concentration of professionals in high-income urban areas.

The classification presented here must be interpreted with caution due to several reasons. Firstly, the data were obtained from different sources and years of publication, focused on 12-year-old children only, and a time period of ten years was arbitrarily selected. Moreover, the classification did not take into account the potential economic limitations of some countries with regard to the collection of epidemiological data on a regular basis. However, despite these limitations, the outcomes of the classification system presented here may be viewed as warning signs for all countries, including those in the green level, as surveillance of risk factors and levels of inequality are very important in all 33 LACCs.

Dental caries is a preventable disease and directing efforts toward controlling it will allow minimization of associated costs in the future. Therefore, epidemiological surveys should be viewed as profitable investments instead of costly endeavors. Finally, health authorities must also bear in mind that the dynamic nature of the carious process provides us with an opportunity to prevent and control it in the early stages. Initiation of long-term regional projects aimed at reducing the burden of dental caries and its impact on the quality of life of the LACC population are necessary.

The Pan-American Health Organization and World Health Organization (WHO) are firmly committed toward supporting countries in their efforts to improve oral public health and sustain health development.[66,67,68] Oral health was included in the Political Declaration on Universal Health Coverage in 2019, and this decision is of particular importance for LACCs as diseases of the oral cavity are the fourth most expensive to treat in terms of out-of-pocket expenditure.[69] Moreover, this new commitment paves the way for a regional and strategic oral health plan in LACCs in the near future.

The International Association of Pediatric Dentistry (IAPD) launched an Early Childhood Caries: IAPD Bangkok Declaration in 2019 to gain support for efforts aimed at reducing the prevalence and burden of early childhood caries (ECC) globally. The four main recommendations were as follows: a) raise awareness of ECC among parents/caregivers, dentists, health professionals, and other stakeholders; b) limit sugar intake for children under two years of age; c) brush teeth twice daily using a fluoridated toothpaste; and d) provide initial preventive guidance in the first year of life.[70] ECC is preventable and affects millions of children in LACCs, highlighting the importance of these recommendations. The first year of the child's life represents an excellent window of opportunity to educate families on the chronic, cumulative nature of dental caries and emphasize the fact that the adult's oral health is dependent on their early life conditions.

The Fédération Dentaire Internationale (FDI) World Dental Federation, which has been investigating dental caries for over 20 years, recently issued a policy statement supporting a shift in caries management from restorative measures to those aimed at monitoring and arresting disease progression, and preventing further lesion development. This document highlights the need to consider disease stage and activity, the patient's condition, their risk of caries, and their aesthetic demands before opting for invasive treatment methods. However, if invasive treatments are unavoidable, a minimum intervention approach should be adopted. The FDI is engaged in improving oral health and the practice of dentistry globally, and this may prove to be very useful for LACCs.[71,72]

The International Caries Detection and Assessment System (ICDAS; 2002) was modified into the International Caries Classification and Management System (ICCMS™) in 2012 and subsequently presented as a clinical practice-friendly version, Caries Care International, in 2019. This charity has been carrying out evidence-based work in collaboration with clinical practices, dental researchers, dental public health officials, and the dental education system to build a health outcomes-focused system that aims to maintain oral health and preserve tooth structure in the long term.[73-76]

The Alliance for a Cavity-Free Future (ACFF), initiated in 2010 and made up of a group of experts

from around the world, joined the efforts to promote integrated clinical and public health actions to prevent disease initiation and progression, and move toward a caries-free future for all age groups. Their goals include ensuring a caries-free future for all children by 2026; changing and improving the caries curriculum of dental schools; working collaboratively with organizations worldwide; promoting integrated, comprehensive, and locally appropriate caries prevention and management systems; and monitoring these approaches. The ACFF consists of 28 Chapters in 540 countries around the world, and the LACC chapters are located in Brazil, Colombia, Mexico, and Venezuela. Furthermore, the ACFF, in collaboration with King's College London and three Dental Policy Labs, have been working toward the development of policies aimed at achieving a caries-free future through allocation of increased resources for disease prevention, paying for health in dentistry, and moving toward better oral and dental health through partnership.[77-80]

Therefore, it is now time to join these efforts and create opportunities from challenges put forth by the COVID-19 pandemic. Despite its impact on future epidemiological studies and health systems, this is a good opportunity for dental associations, policymakers, academic staff, and stakeholders to rethink caries control strategies, endeavor to develop robust oral health plans, and take consistent actions toward achieving sustainable caries-free communities in all LACCs.

Final recommendations

To reduce the prevalence of caries and tackle inequalities, the Latin American Oral Health Association (LAOHA) Dental Caries Prevalence, Prospects, and Challenges for Latin America and Caribbean countries - Caries Consensus made the following recommendations for governments, policymakers, health authorities, professionals, academic staff, industry, and stakeholders.

General recommendations

a. Oral health should be considered a human right. The existence of social gradients in diseases of oral health, including dental caries, requires policies and interventions to ensure access to quality healthcare, safe and a healthy environment, life opportunities and access to resources that are important for health (social determinants of health). This consensus recommends that government and policymakers should be committed to creating and implementing economic and social policies that raise living standards using a proportionate universal approach, particularly for the indigenous population and the most vulnerable groups of LACCs.
b. Develop an agenda in collaboration with dental and health associations, clinicians, dental students, community members, policymakers, and representatives of the general public to promote adoption of evidence-based guidelines for the prevention and comprehensive management of dental caries, taking into consideration the social determinants of health and the specific needs, challenges, and prospects of the LACC region.
c. Develop systematic national epidemiological surveys using comparable caries detection indices with the aim of standardizing comparisons across countries and improving the understanding of caries and its impact on the quality of life of the LACC population. Ideally, these surveys should be conducted around the same period to facilitate cross-national and subregional comparisons over time.
d. Encourage high-quality studies to investigate the interplay between various risk and protective factors on dental caries, particularly among the most vulnerable groups in LACC.
e. Provide evidence on appropriate low-cost therapeutic and restorative techniques for the provision of comprehensive continuous care for the LACC population.
f. Government and food industries should develop policies aimed at reducing sugar concentration in processed and ultra-processed foods in order to reduce the incidence of dental caries and other chronic diseases.
g. Government and health care industries should work together to make effective anti-caries

fluoridated toothpastes easily available for the LACC population.

Specific recommendations

a. Create a dental caries surveillance program for LACCs that can allow classification of countries based on the burden of dental caries and level of inequalities, monitor prevalence of dental caries and its risk factors regularly on a regional level, and allow sharing of successful experiences
b. Implement a Core Cariology Curriculum for dental faculties in LACCs that is based on the provision of additional preventive care and takes the oral health conditions of the region into consideration.
c. Promote upstream measures to limit sugar intake through food and drinks while taking oral health literacy and the social determinants of dental caries into consideration (e.g., by limiting soft drinks and promoting a healthier food environment in schools and workplaces, regulation on advertising and promoting the inclusion of sugar content information on food labels, and sugar taxation).
d. Support efficacious and safe strategies for caries control through the use of fluorides at the community level (e.g., salt or water fluoridation), taking into consideration the local, regional, and national suitability of the strategy.
e. Encourage regular use of fluoridated toothpastes (minimum concentration of 1000 ppm F) at least twice a day at the community level, taking the oral health literacy and economical sustainability of the region into consideration.
f. Considering the effectiveness of fluoridated toothpaste for caries control and the regional water supply issues, particularly in rural areas and city slums, this consensus endorses regular use of fluoridated toothpastes as the main vehicle for topical fluoride application. Additionally, it makes an urgent call to improve access to drinking water in the region, given its importance for general health and well-being.
g. Implementation of a regional legislation that ensures a minimum concentration of soluble fluorides in toothpastes for achievement of appropriate anti-caries effect in LACCs.
h. Implementation of local surveillance systems that guarantee optimal fluoride concentrations in water or salt to provide appropriate anti-caries effects and prevent dental fluorosis.
i. SDF and ART should be considered as population strategies for the treatment of dental caries.
j. Encourage widespread dissemination of high-quality information on the rational use of fluorides and their benefits for controlling dental caries. Additionally, promote provision of information on the drawbacks of excessive sugar intake and its impact on general and oral health.

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Karen Glazer Peres	National Dental Centre Singapore (NDCS)	Singapore
Christina Poh Choo Sim	National Dental Centre Singapore (NDCS)	Singapore
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Miriam Bullen	Panamanian Dental Association (AOP)	Panama

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(1) Máxima Protección Anticaries solo está disponible en México y Centroamérica **(2)**Patrícia Layane de Menezes Macêdo Nascimento. Brazilian Dental Journal (2016) 27(1). Fluoride-Releasing Materials to Prevent White Spot Lesions around Orthodontic Brackets: A Systematic Review. **(3)** A. Nordström D. Birkhed Preventive Effect of High-Fluoride Dentifrice (5,000 ppm) in Caries-Active Adolescents: A 2-Year Clinical Trial

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