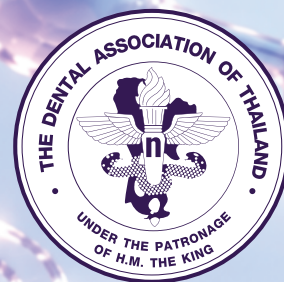


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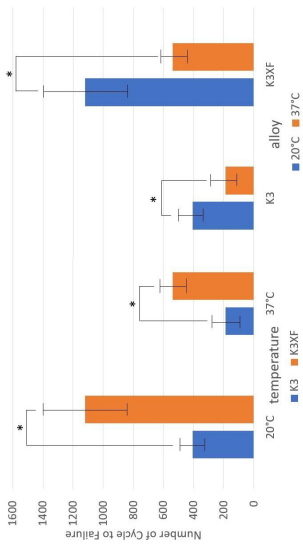
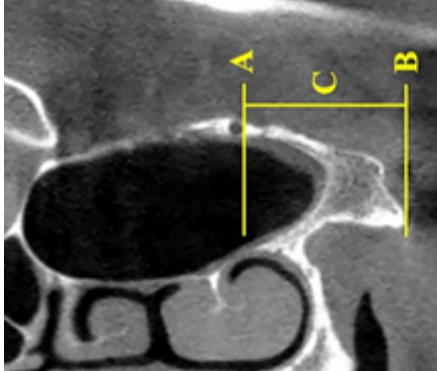
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- Authors

Zhao Y, Zhu J: *In vivo* color measurement of 410 maxillary anterior teeth. *Chin J Dent Res* 1998;1(3):49-51.

- Institutional authors

Council in Dental Materials and Devices. New American Dental Association Specification No.27 for direct filling resins. *J Am Dent Assoc* 1977;94(6):1191-4

- No author

Cancer in South Africa [editorial]. *S Afr Med J* 1994;84:15

Sample of references from books and other monographs

- Authors being writers

Neville BW, Damn DD, Allen CM, Bouquot JE. Oral and maxillofacial pathology. Philadelphia: WB Saunders; 1995. P. 17-20

- Authors being both writer and editor

Norman IJ, Redfern SJ, editors. Mental health care for the elderly people. New York: Churchill Livingstone; 1996.

- Books with authors for each separate chapter

- Books with authors for each separate chapter

and also have editor

Sanders BJ, Handerson HZ, Avery DR. Pit and fissure sealants; In: McDonald RE, Avery DR, editors. Dentistry for the child and adolescent. 7th ed. St Louis: Mosby; 2000. P. 373-83.

- Institutional authors

International Organization for Standardization. ISO/TR 11405 Dental materials-Guidance on testing of adhesion to tooth structure. Geneva: ISO; 1994.

Samples of references from academic conferences

- Conference proceedings

Kimura J, Shibasaki H, editors. R The Journal of the Dental Association of Thailand (JDAT): (ISSN 2408-1434) online open access and double-blind peer review journal and also supported by the Dental Association of Thailand advances in clinical neurophysiology. Proceeding of the 10th International Congress of EMG and Clinical Neurophysiology; 1995 Oct 15-19; Kyoto, Japan. Amsterdam; Elsevier; 1996.

- Conference paper

Hotz PR. Dental plaque control and caries. In: Lang PN, Attstrom R, Loe H, editors. Proceedings of the European Work shop on Mechanical Plaque Control; 1998 May 9-12; Berne, Switzerland. Chicago: Quintessence Publishing; 1998. p. 25-49.

- Documents from scientific or technical reports

Fluoride and human health. WHO Monograph; 1970. Series no.59.

Samples of reference from thesis

Muandmingsuk A. The adhesion of a composite resin to etched enamel of young and old teeth [dissertation]. Texas: The University of Texas, Dental Branch at Houston; 1974.

Samples of reference from these articles are only accepted in electronic format

- Online-only Article (With doi (digital identification object number))

Rasperini G, Acunzo R, Limioli E. Decision making in gingival rec experience. *Clin Adv Periodontics* 2011;1: 41-52. doi:10.1902 cap.2011.1000002.

- Online only article (without doi)

Aboud S. Quality improvement initiative in nursing homes: the ANA acts in an advisory role. *Am J Nurs* 2002; 102(6)[cited 2002 Aug 12] Available from: <http://nursingworld.org/AJN/2002/june/WaWatch.htmArticle>

Samples of references from patents/petty patents

- Patent

Pagedas AC, inventor; Ancel Surgical R&D Inc., assignee. Flexible endoscopic grasping and cutting device and positioning tool assembly. United States patent US 20020103498. 2002 Aug 1.

- Petty patent

Priprem A, inventor, Khon Kaen University. Sunscreen gel and its manufacturing process. Thailand petty patent TH1003001008. 2010 Sep 20.

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Clinical Practice Guidelines for Carious Lesion Management 2026

The Dental Association of Thailand

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Abstract

Dental caries remains one of the most prevalent oral diseases and continues to represent a significant public health challenge in Thailand. Contemporary caries management has shifted from a predominantly restorative approach toward a comprehensive, minimally invasive, and risk-based strategy that emphasizes both disease control and preservation of tooth structure. This article presents the updated 2026 Clinical Practice Guidelines for Carious Lesion Management in Thailand, developed by the Dental Association of Thailand through a structured consensus process and comprehensive review of current scientific evidence. The guidelines utilize the International Caries Detection and Assessment System (ICDAS) and the International Caries Classification and Management System (ICCMS™) to classify lesion severity and guide clinical decision-making. Management recommendations are provided for carious lesions in both primary and permanent dentitions, encompassing occlusal, smooth, proximal, and root surfaces. The updated recommendations emphasize non-invasive and micro-invasive interventions for early lesions, risk-based preventive care, minimally invasive restorative approaches, and preservation of pulp vitality whenever feasible. Significant revisions include greater emphasis on fluoride-based preventive strategies in primary teeth, incorporation of radiographic assessment in treatment planning, expanded indications for minimally invasive restorative management of proximal lesions, recognition of both selective and non-selective carious tissue removal approaches for deep carious lesions in permanent teeth, and updated guidance for root caries management in aging populations. These guidelines aim to support evidence-based, patient-centered, and context-appropriate clinical decision-making while promoting equitable and effective caries management across diverse healthcare settings in Thailand.

Keywords: Caries management, Carious lesion, Clinical practice guidelines, Dental caries, Permanent teeth, Primary teeth

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Introduction

Dental caries remains a significant public health challenge in Thailand. Modern management has shifted from a purely restorative approach to a more holistic strategy, requiring a comprehensive management approach that operates at two distinct levels: the individual level and the lesion level.

At the individual level, the focus is on managing the disease process itself. This is achieved through a thorough Caries Risk Assessment (CRA) to identify the underlying etiological factors unique to each patient. Management strategies at this level include oral health behavioral modification, effective plaque biofilm control, diet modification, and the optimized use of fluoride, all supported by regular monitoring and reinforcement to ensure long-term oral health. In parallel, management at the lesion level involves the clinical assessment and treatment of specific carious manifestations. The primary goal at this level is early caries detection and the implementation of interventions designed to arrest or prevent the progression of initial lesions. By focusing on the lesion level, clinicians can prioritize the preservation of sound tooth structure, aligning with the principles of Minimal Intervention Dentistry (MID).

In 2017, the Dental Association of Thailand introduced guidelines emphasizing MID.¹ These approaches prioritized the preservation of natural tooth structure and the selection of restorative materials based on individual risk. For deep carious lesions, the "Selective Caries Removal to Soft Dentin" technique was advocated to avoid pulp exposure and maintain pulp vitality. However, as dental research evolves, new evidence regarding the efficacy of various techniques and materials has emerged. Specifically, the debate between selective caries removal and non-selective caries removal in permanent teeth—including long-term

outcomes and survival rates—continues to be a critical topic in clinical practice. Furthermore, there are ongoing questions regarding the necessity and effectiveness of non-invasive restoration for managing initial carious lesions in primary teeth. Consequently, there is an urgent need to review and update these guidelines to reflect current scientific evidence and the specific clinical context of Thailand.

Moreover, caries management is currently taught with considerable variation across dental schools in Thailand. Nationally endorsed, evidence-based guidelines would establish a standardized approach to caries detection, diagnosis, and management. Such guidelines would facilitate consistency in dental education, clinical calibration, and the implementation of best practices across diverse clinical settings. In response to this need, the Dental Association of Thailand initiated a national collaborative effort to develop updated guidelines for caries management.

Therefore, the objective of this article is to present the updated 2026 Clinical Practice Guidelines for Carious Lesion Management in Thailand. The target audience for these guidelines includes dentists and dental hygienists. Policy makers may also benefit from using these guidelines.

Guideline Development Process

The development of the guidelines utilized a structured consensus-building approach and a comprehensive review of contemporary dental literature. These guidelines utilize the International Caries Detection and Assessment System (ICDAS) to categorize carious lesions into stages based on clinical appearance and extent of damage, and the International Caries Classification and Management System (ICCMS) for radiographic diagnosis (Table 1).^{2,3} The methodology was divided into three primary phases:

Phase 1: Committee Establishment and Preliminary Review

A working committee of faculty members from various dental schools was established to review and update the previous guidelines¹ based on current scientific evidence and the Thai clinical context. This phase was conducted from March to May 2025.

Phase 2: Academic Seminar and Stakeholder Input

On May 22, 2025, an academic seminar was held to present the proposed guidelines. The seminar was attended by representatives from various institutions,

organizations, and dental associations, together with interested dentists, who contributed valuable feedback and professional perspectives.

Phase 3: Consensus Finalization and Distribution

Following the seminar, all input was synthesized into a final draft. A summary of the consensus was then distributed to all participating agencies to finalize the Clinical Practice Guidelines for Carious Lesion Management in Thailand.

Table 1 ICDAS Clinical Scores and ICCMS™ Radiographic Scores^{2,3}

ICDAS Clinical Scores		Clinical Description
0		Sound tooth surface (no evidence of caries)
1		First visual change in enamel (seen only after air-drying or confined to pits/fissures)
2		Distinct visual change in enamel (visible without drying; wider than natural fissure)
3		Localized enamel breakdown due to caries with no visible dentin
4		Underlying dark shadow from dentin with or without localized enamel breakdown
5		Distinct cavity with visible dentin
6		Extensive distinct cavity with visible dentin involving at least half of the surface

ICCMS™ Radiographic Scores		Radiographic Description
R0		No radiolucency visible (sound surface)
RA1		Radiolucency in the outer half of enamel
RA2		Radiolucency in the inner half of enamel, possibly reaching the enamel-dentin junction (EDJ)
RA3		Radiolucency into the outer third of dentin
RB4		Radiolucency into the middle third of dentin
RC5		Radiolucency into the inner third of dentin, possibly near the pulp
RC6		Radiolucency extends into the pulp chamber; potential pulpal involvement is evident

Guideline Consensus

These guidelines provide comprehensive management for carious lesions in both primary and permanent dentition that have not involved the pulp.

The guidelines address both active and inactive lesions across all tooth surfaces. The standardized terminology and definitions used throughout these guidelines are presented in Table 2.

Table 2 Terminology and definition

Terminology	Definitions
Routine oral care	Brushing twice daily with 1,000-1,500 ppm fluoride; daily floss; limit sugar frequency; regular dental visits according to caries risk.
Non-invasive intervention	No hard tissue removal: caries prevention/inactivation via fluoride, chemical agents (controlled mineral balance), biofilm disruption, and dietary control—personalized according to caries risk. ⁴
Micro-invasive intervention	Micrometer-level removal during etching, e.g., sealing with resin or glass ionomer sealant, or resin infiltration. ⁴ (Remark: Resin-based sealant is preferable unless the isolation is not ideal, glass ionomer sealant could be applied.)

Table 2 Terminology and definition (cont.)

Terminology	Definitions
Minimally invasive restoration	Removal of gross hard tissue using hand or rotary instruments, usually with restoration placement. ⁴
Selective carious tissue removal	Carious tissue is removed until soft or firm dentin is reached, a process also known as partial or incomplete caries removal. ⁵
Non-selective carious tissue removal	Carious tissue is removed until hard dentin is reached, a process also known as complete caries removal. ⁵
Stepwise carious tissue removal	Stepwise carious tissue removal involves initially removing carious tissue until soft dentin is reached, followed by placement of a temporary restoration. After 6-12 months, the temporary restoration and remaining carious tissue are removed until firm dentin is reached, and a permanent restoration is placed. ⁵
Cleansable lesion	Carious lesion that can be maintained plaque-free through routine oral hygiene. ⁶
Non-cleansable lesion	Carious lesion that is difficult to clean due to location or morphology ⁷ , commonly covered by thick plaque before cleaning. ³ Some lesions may be made cleansable through cavity modification techniques. ⁸
Active lesion	The enamel surface appears whitish or yellowish, opaque, and rough when gently probed. Lesions are typically found in plaque stagnation areas, such as the entrances of pits and fissures, near the gingival margin, or above/below contact points on proximal surfaces. These lesions may be covered by thick plaque before cleaning. Upon gentle probing, the dentin feels soft or leathery. ³
Inactive lesion	The enamel surface can appear whitish, brownish, or black. It feels hard and smooth with a shiny appearance when gently probed. Carious lesions on smooth surfaces are typically located away from the gingival margin and may not be covered by thick plaque before cleaning. The dentin, upon gentle probing, is also shiny and hard. ³

The guidelines are organized as follows:

1. Management of Carious Lesions in Primary Teeth

- Occlusal surfaces, pits, and fissures (Table 3)
- Smooth surfaces (labial, buccal, lingual, and proximal surfaces without contact) (Table 4)
- Proximal surfaces with interproximal contact (Table 5)

2. Management of Carious Lesions in Permanent Teeth

- Occlusal surfaces, pits, and fissures (Table 6)
- Smooth surfaces (labial, buccal, lingual, and proximal surfaces without contact) (Table 7)
- Proximal surfaces with interproximal contact (Table 8)
- Root surfaces (Table 9)

Table 3 Management of Carious Lesions on Occlusal Surfaces and Pits and Fissures in Primary Teeth

Characteristics of carious lesion					Management approach ^a
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores	Activity	Clinical® and radiographic appearance	
Initial lesion	1-2	R0, RA1-2	Inactive	Clinical: White or brown-black enamel discoloration, visible when wet or dry, with a shiny, hard, smooth surface, free of plaque and cavitation Radiographic: No radiolucency or radiolucency in the outer or inner half of enamel	Routine oral care

Table 3 Management of Carious Lesions on Occlusal Surfaces and Pits and Fissures in Primary Teeth (cont.)

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores	Activity	Clinical® and radiographic appearance	Management approach ^a
Initial lesion	1	R0, RA1-2	Active	Clinical: No carious discoloration when wet; after air drying, carious opacity appears along with plaque accumulation OR Carious discoloration confined to the pit and fissure area (whether seen wet or dry), free of cavitation Radiographic: No radiolucency or radiolucency in the outer half or inner half of the enamel	1. Reinforcing brushing with 1,450 – 1,500 ppm fluoride toothpaste ^{9,10} along with surface remineralization such as fluoride varnish <i>When caries progression cannot be controlled by method 1, consider proceeding with method 2</i>
	2	R0, RA1-2	Active	Clinical: Whitish or yellowish, opaque or dull; rough surface with plaque deposits, OR Carious discoloration extending beyond the natural fissure, free of cavitation Radiographic: No radiolucency, or radiolucency in the outer or inner half of enamel	2. Sealant - Resin-based sealant ¹¹⁻¹⁴ - Glass ionomer sealant ^{*12,15}
Moderate lesion	3	RA1-2	Inactive	Clinical: Localized enamel breakdown without visible dentin; hard surface with brown or black discoloration, plaque-free. Radiographic: Radiolucency in the outer or inner half of enamel	Routine oral care
			Active	Clinical: Localized enamel breakdown without visible dentin; soft surface with plaque deposition Radiographic: Radiolucency in the outer or inner half of enamel	- Resin-based sealant ¹¹⁻¹⁴ - Glass ionomer sealant ^{*12,15,16}
		RA3	Probably Active/ Active	Clinical: Localized enamel breakdown without visible dentin Radiographic: Radiolucency in the outer third of dentin	- Resin-based sealant ¹¹⁻¹⁴ - Glass ionomer sealant ^{*12,15,16} - Minimally invasive restoration ^{9,16} for radiolucency in dentin with high risk of enamel surface fracture
		RB4	Probably Active/ Active	Clinical: Localized enamel breakdown without visible dentin Radiographic: Radiolucency in the middle third of dentin	Minimally invasive restoration ^{9,16}
	4	RA3	Probably active/ Active	Clinical: Underlying dark dentin shadow visible through enamel, with or without enamel breakdown Radiographic: Radiolucency within the outer third of dentin	- Resin-based sealant ¹¹⁻¹⁴ - Glass ionomer sealant ^{*12,15,16} - Minimally invasive restoration ^{9,16} for widespread reflective shadows with high risk of enamel surface fracture
		RB4	Probably active/ Active	Radiographic: Radiolucency within the middle third of dentin	Minimally invasive restoration ^{9,16}

Table 3 Management of Carious Lesions on Occlusal Surfaces and Pits and Fissures in Primary Teeth (cont.)

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores	Activity	Clinical® and radiographic appearance	Management approach ^a
Extensive lesion	5	RB4-RC5	Inactive	Clinical: Distinct cavity with visible dentin involving less than half of tooth surface. Dentin is hard, brown, or black color, and plaque-free Radiographic: Radiolucency within the middle or inner third of dentin, normal furcation and periapical area	- Routine oral care - Minimally invasive restoration ^{9,16} OR ART ¹⁷⁻¹⁹ OR SMART ²⁰⁻²² when indicated for masticatory function, space maintenance, esthetics, or oral hygiene facilitation
			Active	Clinical: Distinct cavity with visible dentin involving less than half of tooth surface. Dentin is soft or leathery on gentle probing, no spontaneous pain Radiographic: Radiolucency within the middle or inner third of dentin, normal furcation and periapical area	- Minimally invasive restoration ^{9,16} - ART ^{*,17-19} - SMART ^{*,20-22} - 38% SDF ^{*,#12,23}
	6	RB4-RC5	Inactive	Clinical: Extensive distinct cavity involves at least half of a tooth surface. Dentin is hard, brown, or black color, and plaque free Radiographic: Radiolucency within the middle or inner third of dentin, normal furcation and periapical area	- Routine oral care - Minimally invasive restoration, SSC ¹⁹ OR ART ¹⁷⁻¹⁹ OR SMART ²⁰⁻²² when indicated for masticatory function, space maintenance, esthetics, or oral hygiene facilitation
			Active	Clinical: Extensive distinct cavity involves at least half of a tooth surface. Dentin is soft or leathery on gentle probing, no spontaneous pain Radiographic: Radiolucency within the middle or inner third of dentin, normal furcation and periapical area	- Minimally invasive restoration ^{9,16} - SSC ^{§,19} - ART ^{*,17-19} - SMART ^{*,20-22} - 38% SDF ^{*,#12,23}
		RC6	Active	Radiolucency into the pulp is highly likely to require pulp treatment, which is beyond the scope of these guidelines.	

^aClinical findings may be confirmed by gentle examination using a WHO/CPI/PSR probe or blunt instrument (avoid a sharp explorer).

^oTreatment priority follows numbering; bullets (-) or "OR" indicate equal options.

^{*} In cases where moisture control is difficult, such as when children are uncooperative or in field dental settings.

[#] Esthetic concern must be considered.

[§]Consider SSC for multi-surface carious tooth, high recurrent caries risk, or treatment under general anesthesia.

SSC: Stainless steel crown; ART: Atraumatic restorative treatment; SMART: Simplified and modified atraumatic restorative treatment or Silver modified atraumatic restorative treatment; SDF: Silver diamine fluoride.

Table 4 Management of Carious Lesions on Labial, Buccal, Lingual, Open Contact Proximal Surface in Primary Teeth

Characteristics of carious lesion				
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores ^b	Activity	Clinical® and radiographic ^b appearance
Initial lesion	1-2		Inactive	White or brown-black enamel discoloration, visible when wet or dry, with a shiny, hard, smooth surface, free of plaque and cavitation

Table 4 Management of Carious Lesions on Labial, Buccal, Lingual, Open Contact Proximal Surface in Primary Teeth (cont.)

Severity	Characteristics of carious lesion				Management approach ^a
	ICDAS Clinical scores	ICCMS™ Radiographic scores ^b	Activity	Clinical ^c and radiographic ^b appearance	
Initial lesion	1		Active	When wet, no discoloration is seen; after air drying, carious opacity appears. Having plaque deposition	Reinforce brushing with 1,450 – 1,500 ppm fluoride toothpaste ^{9,10} along with surface remineralization such as fluoride varnish ^{10,12,16}
	2		Active	Whitish/yellowish; opaque, dull surface, rough to probe touch, with plaque deposition	
Moderate lesion	3		Inactive	Localized enamel breakdown without visible dentin; hard surface, brown or black discoloration, plaque-free	- Routine oral care - Minimally invasive restoration ^{9,16} when indicated for esthetics, or oral hygiene facilitation
			Active	Localized enamel breakdown without visible dentin, soft surface with plaque deposition	- Reinforce brushing with 1,450 – 1,500 ppm fluoride toothpaste ^{9,10} along with surface remineralization such as fluoride varnish ^{10,12,16}
	4		Probably active / Active	Underlying dark dentin shadow visible through enamel, with or without slight enamel breakdown	- Minimally invasive restoration ^{9,16} when esthetic concern or non-cleansable lesion
Extensive lesion	5-6		Inactive	Distinct or extensive cavity with visible dentin. Dentin is hard, brown, or black color, and plaque-free	- Routine oral care - Minimally invasive restoration ^{9,16} , ART ¹⁷⁻¹⁹ or SMART ²⁰⁻²² when indicated for esthetics, or oral hygiene facilitation
			Active	Distinct or extensive cavity with visible dentin. Dentin is soft or leathery on gentle probing	- Minimally invasive restoration ^{9,16} - SSC ^{§,19} - ART ^{*,17-19} - SMART ^{*,20-22} - 38% SDF ^{*,#,12,23}

^c Clinical findings may be confirmed by gentle examination using a WHO/CPI/PSR probe or blunt instrument (avoid a sharp explorer).

^a Treatment priority follows numbering; bullets (-) or “OR” indicate equal options

^b For buccal or lingual/palatal lesions, the depth of lesion cannot be assessed from radiographs. Therefore, the depth of caries relies on clinical appearance of caries, symptoms, and operator’s experience.

^{*} In cases where moisture control is difficult, such as when children are uncooperative or in field dental settings.

[#] Esthetic concern must be considered.

[§] Consider SSC for multi-surface carious tooth, high recurrent caries risk, or treatment under general anesthesia.

SSC: Stainless steel crown; ART: Atraumatic restorative treatment; SMART: Simplified and modified atraumatic restorative treatment or Silver modified atraumatic restorative treatment; SDF: Silver diamine fluoride.

Table 5 Management of Carious Lesions on Proximal Surface (with contact) in Primary Teeth

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores ^c	Activity	Clinical® and radiographic appearance	Management approach ^a
Initial lesion		RA1	Active	Clinical: Occlusal view sound; proximal surface (after separation) shows rough or smooth, white/yellowish, opaque, dull surface, with plaque deposits Radiographic: Radiolucency in the outer half of the enamel	- Reinforce brushing with 1,450 – 1,500 ppm fluoride toothpaste and clean proximal areas, along with surface remineralization such as fluoride varnish ^{10,12,24}
		RA2	Active	Clinical: Occlusal view sound or marginal ridge discoloration; proximal surface (after separation) shows rough or smooth, white/yellowish, opaque, dull surface, with plaque deposits Radiographic: Radiolucency in the inner half of enamel	
		RA3	Active	Clinical: Occlusal view appears sound or marginal ridge discoloration. If tooth is separated, proximal surface reveals white, yellowish, opaque, dull surface, with rough or smooth texture or small cavitation and plaque presence Radiographic: Radiolucency limited to the outer third of dentin	- Reinforce brushing with 1,450 – 1,500 ppm fluoride toothpaste and clean proximal areas, along with surface remineralization such as fluoride varnish ^{10,12,24} - Minimally invasive restoration ^{9,16} for cases with active carious lesions on other teeth or surfaces, high caries risk, limited ability to attend regular follow-up visits or when cavitated lesion is clinically detected
Moderate lesion		RB4	Active	Clinical: Marginal ridge shows discoloration or distinct cavity Radiographic: Radiolucency in the middle third of dentin	- Minimally invasive restoration ^{9,16} - SSC ^{5,19} - ART ^{*,17-19} - SMART ^{*,20-22} - 38% SDF ^{*,#12,23}
Extensive lesion		RC5	Active	Clinical: Marginal ridge breakdown or distinct cavity, no spontaneous pain Radiographic: Radiolucency in the inner third of dentin, normal furcation and periapical area	
		RC6	Active	Radiolucency into the pulp is highly likely to require pulp treatment, which is beyond the scope of these guidelines.	

[®]Clinical findings may be confirmed by gentle examination using a WHO/CPI/PSR probe or blunt instrument (avoid a sharp explorer).

[°]Treatment priority follows numbering; bullets (-) or "OR" indicate equal options.

^cFor proximal lesions, lesion depth is primarily assessed and classified using radiographs.

^{*}In cases where moisture control is difficult, such as when children are uncooperative or in field dental settings.

[#] Esthetic concern must be considered.

⁵Consider SSC for multi-surface carious tooth, high recurrent caries risk, or treatment under general anesthesia.

SSC: Stainless steel crown; ART: Atraumatic restorative treatment; SMART: Simplified and modified atraumatic restorative treatment or Silver modified atraumatic restorative treatment; SDF: Silver diamine fluoride.

Table 6 Management of Carious Lesions on Occlusal Surfaces and Pits and Fissures in Permanent Teeth

Severity	Characteristics of carious lesion				Management approach ^a
	ICDAS Clinical scores	ICCMS™ Radiographic scores	Activity	Clinical® and radiographic appearance	
Initial lesion	1-2	R0, RA1-2	Inactive	Clinical: White or brown-black enamel discoloration, visible when wet or dry, with a shiny, hard, smooth surface, free of plaque and cavitation Radiographic: No radiolucency or radiolucency in the outer or inner half of enamel	Routine oral care with monitoring ^{4,7,25-28}
	1	R0, RA1-2	Active	Clinical: No carious discoloration when wet; after air drying, carious opacity appears along with plaque accumulation OR Carious discoloration confined to the pit and fissure area (whether seen wet or dry), free of cavitation Radiographic: No radiolucency or radiolucency in the outer half or inner half of the enamel	- <i>Potentially cleansable lesion with motivation:</i> Non-invasive, risk-based intervention with monitoring ^{8,16} - <i>Non-cleansable lesion:</i> Sealant with or without fluoride varnish; requires monitoring ^{12,25,29}
	2	R0, RA1-2	Active	Clinical: Whitish or yellowish, opaque or dull; rough surface with plaque deposits, OR Carious discoloration extending beyond the natural fissure, free of cavitation Radiographic: No radiolucency, or radiolucency in the outer or inner half of enamel	
Moderate lesion	3	RA1-2	Inactive	Clinical: Localized enamel breakdown without visible dentin; hard surface, brown or black discoloration, and plaque-free Radiographic: Radiolucency in the outer or inner half of enamel	- Routine oral care ^{4,7,25-28} OR Non-invasive intervention with monitoring ³⁰ - (Optional) Sealant with monitoring OR minimally invasive restoration for questionable lesions or functional/esthetic concerns ^{4,26}
			Active	Clinical: Localized enamel breakdown without visible dentin; soft surface with plaque deposits Radiographic: Radiolucency in the outer or inner half of enamel	- <i>Potentially cleansable lesion with motivation:</i> Non-invasive, risk-based intervention with monitoring ^{8,16,31} - (Optional) Minimally invasive restoration for functional/esthetic concerns ^{4,26} - <i>Non-cleansable lesion:</i> Sealant with monitoring OR Minimally invasive restoration ^{4,16,26,27,31,32}
		RA3-RB4	Active	Clinical: Localized enamel breakdown with radiographic extension deep into the dentin Radiographic: Radiolucency within the outer or middle third of dentin	Minimally invasive restoration ^{4,6,16,26} : consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33}

Table 6 Management of Carious Lesions on Occlusal Surfaces and Pits and Fissures in Permanent Teeth (cont.)

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores	Activity	Clinical® and radiographic appearance	Management approach ^a
Moderate lesion	4	RA3-RB4	Active	Clinical: Underlying dark dentin shadow visible through enamel, with or without slight enamel breakdown Radiographic: Radiolucency within the middle third of dentin	Minimally invasive restoration ^{4,6,16,26} : consider selective removal to firm dentin or non-selective caries removal, with a well-sealed restoration ^{5,33}
		RC5	Active	Clinical: Underlying dark dentin shadow visible through enamel, with or without slight enamel breakdown; no spontaneous pain; no response to percussion; positive response to electrical/cold sensibility tests Radiographic: Radiolucency in the inner third of dentin (Deep caries ³⁴); normal periapical area	Minimally invasive restoration ^{4,6,16,26} : consider selective or non-selective caries removal ^{5,33,35-37} - Selective caries removal: optional base material: RMGIC or CSC with a well-sealed restoration ^{5,33-40} - Non-selective caries removal: CSC is preferable when in close proximity to the pulp or pulp exposure, followed by a well-sealed restoration ^{5,33,35-39,41-43}
		RC6	Active	Radiolucency into the pulp (Extremely deep caries ³⁴) is highly likely to require pulp treatment, which is beyond the scope of these guidelines.	
Extensive lesion	5-6	RB4	Inactive	Clinical: Distinct or extensive distinct cavities with visible dentin, hard, brown, or black color, and plaque-free Radiographic: Radiolucency within the middle third of dentin	1. Routine oral care ^{4,7,25-28} OR Non-invasive intervention with monitoring ³⁰ 2. If restoration is needed, consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33}
			Active	Clinical: Distinct or extensive distinct cavities with visible dentin; no spontaneous pain; no response to percussion; positive response to electrical/cold sensibility tests Radiographic: Radiolucency within the middle third of dentin	Minimally invasive restoration ^{4,6,16,26} : consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33}
		RC5	Inactive	Clinical: Distinct or extensive distinct cavities with visible dentin, hard, brown, or black color, and plaque-free Radiographic: Radiolucency in the inner third of dentin (Deep caries ³⁴); normal periapical area	1. Routine oral care ^{4,7,25-28} OR Non-invasive intervention with monitoring ³⁰ 2. If restoration is needed, consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33,35-37} - Selective caries removal: optional base material: RMGIC or CSC with a well-sealed restoration ^{5,33-40} - Non-selective caries removal: CSC is preferable when in close proximity to the pulp or pulp exposure, followed by a well-sealed restoration ^{5,33,35-39,41-43}

Table 6 Management of Carious Lesions on Occlusal Surfaces and Pits and Fissures in Permanent Teeth (cont.)

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores	Activity	Clinical® and radiographic appearance	Management approach ^a
			Active	Clinical: Distinct or extensive distinct cavities with visible dentin; no spontaneous pain; no response to percussion; positive response to electrical/cold sensibility tests Radiographic: Radiolucency in the inner third of dentin (Deep caries ³⁴); normal periapical area	Minimally invasive restoration ^{4,6,16,26} : consider selective or non-selective caries removal ^{15,33,35-37} - Selective caries removal: optional base material: RMGIC or CSC with a well-sealed restoration ^{5,33-40} - Non-selective caries removal: CSC is preferable when in close proximity to the pulp or pulp exposure, followed by a well-sealed restoration ^{5,33,35-39,41-43}
		RC6	Active	Radiolucency into the pulp (Extremely deep caries ³⁴) is highly likely to require pulp treatment, which is beyond the scope of these guidelines.	

[®] Clinical findings may be confirmed by gentle examination using a WHO/CPI/PSR probe or blunt instrument (avoid a sharp explorer).

[°]Treatment priority follows numbering; bullets (-) or "OR" indicate equal options.

Consider 38% SDF for cavitated lesions with dentin exposure when restoration is not feasible.²⁵

CSC: calcium silicate cement; RMGIC: resin-modified glass ionomer cement

Table 7 Management of Carious Lesions on Labial, Buccal, Lingual, Open Contact Proximal Surface in Permanent Teeth

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores ^b	Activity	Clinical® and radiographic ^b appearance	Management approach ^a
Initial lesion	1-2		Inactive	White or brown-black enamel discoloration, visible when wet or dry, with a shiny, hard, smooth surface, free of plaque and cavitation	Routine oral care with monitoring ^{4,7,25-28}
			Active	Whitish or yellowish, opaque or dull, with a rough surface and plaque deposits, free of cavitation	Non-invasive, risk-based intervention with monitoring ^{8,12,16,29}
Moderate lesion	3		Inactive	Localized enamel breakdown without visible dentin; hard surface, brown or black discoloration, and plaque-free	Routine oral care ^{4,7,25-28} OR Non-invasive, risk-based intervention with monitoring ³⁰ - (Optional) Minimally invasive restoration for functional/esthetic concerns ^{4,26}
			Active	Localized enamel breakdown without visible dentin; soft surface with plaque deposits	- <i>Potentially cleansable lesion with motivation:</i> Non-invasive, risk-based intervention with monitoring ^{8,16} - (Optional) Minimally invasive restoration for functional/esthetic concerns ^{4,26}

Table 7 Management of Carious Lesions on Labial, Buccal, Lingual, Open Contact Proximal Surface in Permanent Teeth (cont.)

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores ^b	Activity	Clinical [®] and radiographic ^b appearance	Management approach ^a
					- Potentially cleansable lesion after <i>transformation</i> (enamel reshaping); followed by surface remineralization such as fluoride varnish with monitoring^{8,16,44} - Non-cleansable lesion: Micro-invasive intervention with monitoring OR Minimally invasive restoration^{4,16,26,27,32}
	4		Active	Underlying dark dentin shadow visible through enamel, with or without slight enamel breakdown; no spontaneous pain; no response to percussion; positive response to electrical/cold sensibility tests	Minimally invasive restoration ^{4,6,16,26} : consider selective or non-selective caries removal ^{5,33,35-37}
Extensive lesion	5-6		Inactive	Distinct or extensive distinct cavities with visible dentin, hard, brown, or black color, and plaque-free; no spontaneous pain; no response to percussion; positive response to electrical/cold sensibility tests; normal periapical area	1. Routine oral care^{4,7,25-28} OR Non-invasive intervention with monitoring³⁰ 2. If restoration is needed, consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration^{5,33,35-37} - <i>Selective caries removal</i>: optional base material: RMGIC or CSC with a well-sealed restoration^{5,33-40} - <i>Non-selective caries removal</i>: CSC is preferable when in close proximity to the pulp or pulp exposure, followed by a well-sealed restoration^{5,33,35-39,41-43}
			Active	Distinct or extensive distinct cavities with visible dentin; no spontaneous pain; no response to percussion; positive response to electrical/cold sensibility tests; normal periapical area	Minimally invasive restoration^{4,6,16,26}: consider selective or non-selective caries removal^{5,33,35-37} - <i>Selective caries removal</i>: optional base material: RMGIC or CSC with a well-sealed restoration^{5,33-40} - <i>Non-selective caries removal</i>: CSC is preferable when in close proximity to the pulp or pulp exposure, followed by a well-sealed restoration^{5,33,35-39,41-43}

[®] Clinical findings may be confirmed by gentle examination using a WHO/CPI/PSR probe or blunt instrument (avoid a sharp explorer).

^a Treatment priority follows numbering; bullets (-) or "OR" indicate equal options

^b For buccal or lingual/palatal lesions, the depth of lesion cannot be assessed from radiographs. Therefore, the depth of caries relies on clinical appearance of caries, symptoms, and operator's experience. For moderate/advanced proximal lesions with no adjacent teeth, the depth of caries should be assessed with radiograph. The management should be the same as proximal lesion with contact.

Consider 38% SDF for cavitated lesions with dentin exposure when restoration is not feasible.²⁵

CSC: Calcium silicate cement; RMGIC: Resin-modified glass ionomer cement

Table 8 Management of Carious Lesions on Proximal Surface (with contact) in Permanent Teeth

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores ^c	Activity	Clinical® and radiographic appearance	Management approach ^a
Initial lesion		RA1-2	Inactive	Clinical: Occlusal view sound; proximal surface shows non-cavitated (after separation [§]) or localized enamel breakdown without visible dentin; shiny, hard, brown/black surface, and plaque-free Radiographic: Radiolucency in the outer or inner half of enamel	Routine oral care with monitoring ^{45,46}
			Active	Clinical: Occlusal view sound or marginal ridge discoloration; proximal surface shows non-cavitated (after separation [§]) or localized enamel breakdown without visible dentin; rough or soft, white/yellowish; opaque, dull surface, with plaque deposits Radiographic: Radiolucency in the outer or inner half of enamel	- <i>Non-cavitated lesions:</i> Non-invasive, risk-based intervention with monitoring ^{12,25,29} OR Micro-invasive intervention with or without fluoride varnish; required monitoring ^{12,29,45} - <i>Cavitated lesions:</i> Minimally invasive restoration ⁴⁵⁻⁴⁷ : consider selective removal to firm dentin or non-selective caries removal with a wellsealed restoration ^{5,33}
		RA3	Probably active	Clinical: Occlusal view sound or marginal ridge discoloration; proximal surface shows non-cavitated (after separation [§]); likely seen around proximal areas with plaque deposits Radiographic: Radiolucency within the outer third of dentin	Non-invasive, risk-based intervention with monitoring ^{12,25,29} OR Micro-invasive intervention with or without fluoride varnish; required monitoring OR Minimally invasive restoration ^{29,45-48} ; depends on the lesion depth
			Active	Clinical: Localized enamel breakdown may be visible from the occlusal, buccal, or lingual side; commonly seen in proximal areas with plaque deposits Radiographic: Radiolucency within the outer third of dentin	Minimally invasive restoration ⁴⁵⁻⁴⁷ : consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33,44-46}
			Inactive	Clinical: Distinct cavity with visible dentin, hard, brown, or black color, and plaque-free Radiographic: Radiolucency within the middle third of dentin	1. Routine oral care ^{4,7,25-28} OR Non-invasive intervention with monitoring ³⁰ 2. If restoration is needed, consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33}
			Active	Clinical: Marginal ridge shows discoloration or distinct cavity with visible dentin; commonly seen in proximal areas with plaque deposits Radiographic: Radiolucency within the middle third of dentin	Minimally invasive restoration ⁴⁵⁻⁴⁷ : consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33}
Moderate lesion		RB4	Inactive	Clinical: Distinct cavity with visible dentin, hard, brown, or black color, and plaque-free Radiographic: Radiolucency within the middle third of dentin	1. Routine oral care ^{4,7,25-28} OR Non-invasive intervention with monitoring ³⁰ 2. If restoration is needed, consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33}
			Active	Clinical: Marginal ridge shows discoloration or distinct cavity with visible dentin; commonly seen in proximal areas with plaque deposits Radiographic: Radiolucency within the middle third of dentin	Minimally invasive restoration ⁴⁵⁻⁴⁷ : consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33}

Table 8 Management of Carious Lesions on Proximal Surface (with contact) in Permanent Teeth (cont.)

Characteristics of carious lesion					
Severity	ICDAS Clinical scores	ICCMS™ Radiographic scores ^c	Activity	Clinical® and radiographic appearance	Management approach ^a
Extensive lesion		RC5	Inactive	Clinical: Distinct or extensive distinct cavities with visible dentin, hard, brown, or black color, and plaque-free; no spontaneous pain; no response to percussion; positive response to electrical/cold sensibility tests Radiographic: Radiolucency in the inner third of dentin (Deep caries ³⁴); normal periapical area	1. Routine oral care ^{4,7,25-28} OR Non-invasive intervention with monitoring ³⁰ 2. If restoration is needed, consider selective removal to firm dentin or non-selective caries removal with a well-sealed restoration ^{5,33,35-37} - <i>Selective caries removal:</i> optional base material: RMGIC or CSC with a well-sealed restoration ^{5,33-40} - <i>Non-selective caries removal:</i> CSC is preferable when in close proximity to the pulp or pulp exposure, followed by a well-sealed restoration ^{5,33,35-39,41-43}
			Active	Clinical: Marginal ridge shows discoloration or distinct/extensive distinct cavity with visible dentin; commonly seen in proximal areas with plaque deposits; no spontaneous pain; no response to percussion; positive response to electrical/cold sensibility tests; normal periapical area	Minimally invasive restoration ^{4,6,16,26} : consider selective or non-selective caries removal ^{5,33,35-37} - <i>Selective caries removal:</i> optional base material: RMGIC or CSC with a well-sealed restoration ^{5,33-40} - <i>Non-selective caries removal:</i> CSC is preferable when in close proximity to the pulp or pulp exposure, followed by a well-sealed restoration ^{5,33,35-39,41-43}
			RC6	Active	RC6 is very likely to involve pulp treatment, which is beyond the scope of these guidelines.

[®] Clinical findings may be confirmed by gentle examination using a WHO/CPI/PSR probe or blunt instrument (avoid a sharp explorer).

^a Treatment priority follows numbering; bullets (-) or "OR" indicate equal options.

^c For proximal lesions, lesion depth is primarily assessed and classified using radiographs.

⁵ Tooth separation with orthodontic separator for evaluating surface integrity and lesion activity may be required.⁴⁹

Consider 38% SDF for cavitated lesions with dentin exposure when restoration is not feasible.²⁵

CSC: Calcium silicate cement; RMGIC: Resin-modified glass ionomer cement

Table 9 Management of Carious Lesions on Root surface in Permanent Teeth

Characteristics of Dental Caries				Management approach ^a
Surface texture	ICDAS Clinical scores	Activity	Caries risk	
Smooth or irregularities from non-carious cervical lesion (NCCL)	0	None	Low	Routine oral care+ and reassessment every 6 months ⁵⁰
			Moderate to high	1. Routine oral care preferably with prescribed 5000 ppm fluoridated toothpaste* ⁵¹ 2. Professionally used: 5% NaF varnish every 6 months with routine oral care ¹²

Table 9 Management of Carious Lesions on Root surface in Permanent Teeth (cont.)

Characteristics of Dental Caries				Management approach ^a
Surface texture	ICDAS Clinical scores	Activity	Caries risk	
Concavity/Initial lesion (< 0.5 mm)	1	Inactive	Low	Routine oral care and reassessment every 6 months ⁵⁰
			Moderate to high	1. Routine oral care with preferably prescribed 5000 ppm fluoridated toothpaste ⁵¹ 2. Professionally used: 5% NaF varnish every 3-4 months with routine oral care ^{12,52} OR Professionally used: 38% SDF [#] solution annually with routine oral care ^{53,54}
		Active	Low	1. Routine oral care with prescribed 5000 ppm fluoridated toothpaste ⁵¹ 2. Professionally used: 5% NaF varnish every 3-4 months with routine oral care ^{12,52} OR Professionally used: 38% SDF [#] solution annually with routine oral care ⁵³
			Moderate to high	1. Routine oral care with prescribed 5000 ppm fluoridated toothpaste ⁵¹ 2. Professionally used: 5% NaF varnish every 3-4 months with routine oral care ^{12,52} OR Professionally used: 38% SDF [#] solution annually with routine oral care ⁵³⁻⁵⁵
Cavitation/moderate to extensive lesion (> 0.5 mm)	2	Inactive	Low	1. Minimally invasive restoration is indicated only for esthetic reason ⁵⁴ in combination with routine oral care and reassessment every 6 months ^{52,57,58} 2. Additional professional application of 38% SDF [#] solution annually may be considered when restorative treatment is not feasible. For non-cleansable lesions, recontouring or restoration may be required to facilitate plaque control ^{153,54,56}
			Moderate to high	1. Minimally invasive restoration in combination with routine oral care and reassessment every 6 months ^{52,57} 2. Additional professional application of 38% SDF [#] solution annually may be considered when restorative treatment is not feasible. For non-cleansable lesions, recontouring or restoration may be required to facilitate plaque control ^{153,54,56}
		Active	Moderate to high	1. Minimally invasive restoration in combination with 5% NaF varnish every 3-4 months with routine oral care ^{12,52,58} 2. Additional professional application of 38% SDF [#] solution annually may be considered when restorative treatment is not feasible. For non-cleansable lesions, recontouring or restoration may be required to facilitate plaque control ^{153,54,56}

^a Treatment priority follows numbering; bullets (-) or "OR" indicate equal options

⁺ Routine oral care with 1,450-1,500 ppm fluoride toothpaste

[#] Esthetic concern must be considered.

Discussion

The 2026 Clinical Practice Guidelines for Carious Lesion Management in Thailand adopt the International Caries Detection and Assessment System (ICDAS) for caries classification.^{2,3} While the management approaches are grounded in international evidence, they have been

carefully adapted to reflect the Thai population context. Notably, several management recommendations for both primary and permanent teeth have been updated from the 2017 Thai Clinical Practice Guidelines¹ to better align with current evidence and local needs.

As part of the ICDAS system, these guidelines reaffirm the recommendation to use WHO/CPI/PSR probe for lesion assessment.² However, because these probes are not routinely available in many clinical settings, the use of a blunt instrument with gentle pressure, rather than a sharp explorer, is considered an acceptable alternative for caries detection.⁵⁹ This recommendation is based on evidence that probing with a sharp explorer may irreversibly damage demineralized non-cavitated enamel, potentially converting a reversible lesion into a cavitated lesion that can no longer be remineralized.⁶⁰ In contrast, blunt instruments are associated with substantially less surface damage and are more consistent with the principles of MID.⁵⁹ By explicitly restating this recommendation, the guidelines aim to encourage more consistent adoption of atraumatic caries examination techniques and support minimally invasive management in clinical practice.

The management of carious lesions in primary teeth has been substantially revised in four key areas. First, for initial occlusal carious lesions, the updated guidelines place greater emphasis on arresting lesion progression through toothbrushing with 1,450–1,500 ppm fluoride toothpaste, rather than relying primarily on fissure sealants. The evidence supporting the effectiveness of fissure sealants in primary teeth remains inconclusive.¹¹⁻¹⁵ Moreover, occlusal caries in primary teeth commonly develops at a young age when fissures are deep and children are often uncooperative during dental treatment, leading to a high risk of sealant failure and potentially negative dental experiences. Therefore, actively encouraging toothbrushing with fluoride toothpaste on the affected area is considered a more appropriate and practical approach than sealant placement, with the additional benefit of protecting adjacent teeth. Second, for moderate occlusal carious lesions (ICDAS 3 and 4), the previous guidelines primarily recommended fissure sealants. The updated guidelines now recommend incorporating radiographic assessment into clinical decision-making. If the lesion has progressed into dentin or poses a significant risk of enamel fracture, minimally invasive restoration should be considered over sealant placement. Third, for proximal carious lesions at the RA3 level, the likelihood of cavitation

has been reported to range from 14% to 61%, depending on the caries risk level of the patient.⁶¹⁻⁶⁶ The previous guidelines primarily recommended surface remineralization and closed monitoring in the absence of clinically detectable cavitation.¹ However, detecting cavitation in closed proximal contacts is inherently challenging. Given the high prevalence of dental caries among Thai children, the updated guidelines now include minimally invasive restoration as a management option for proximal carious lesions. This approach is particularly recommended when the patient presents with a very high caries risk, multiple proximal carious lesions of moderate/extensive depth, or when follow-up to monitor lesion progression cannot be assured. Fourth, the updated guidelines introduce a more flexible and comprehensive range of management options for extensive carious lesions. Recognizing the diversity of clinical environments and patient needs across Thailand, dentists are encouraged to tailor their approach according to their work setting, whether clinical, outreach, or school-based, and the individual patient's level of cooperation. This patient-centered and context-sensitive framework aims to promote inclusive and equitable carious lesion management across all care settings.

Management strategies for lesions in the permanent dentition have also been significantly revised, particularly for deep carious lesions. First, for ICDAS 5 cavitated dentin lesions with radiolucency extending to the inner third of dentin (RC5) in the absence of clear signs of pulpal involvement, the updated guidelines recommend a broader and more adaptable spectrum of therapeutic approaches.³ Treatment at this stage typically involves caries removal followed by restoration with resin composite or glass ionomer cement, with the primary aim of achieving a well-sealed restoration to limit bacterial penetration.^{8,16,30,33} When conventional restorative care is not feasible — such as in cases of limited patient cooperation or restricted access to care — silver diamine fluoride (SDF) is recommended as a practical option to arrest disease progression, particularly in outreach and school-based settings where restorative infrastructure may be limited.^{20,23,28,32} Second, the selection of a caries removal strategy is recognized

as a critical determinant of treatment outcome. Selective caries removal preserves soft or firm dentin near the pulp, thereby reducing the risk of pulp exposure and unnecessary loss of tooth structure, although it requires closer monitoring and appropriate follow-up.¹⁶ In contrast, non-selective (complete) removal eliminates all infected and demineralized tissue, offering enhanced procedural predictability and restoration sealing, but at a higher risk of pulp exposure and greater sacrifice of tooth structure.^{16,34}

Whereas the previous Thai guidelines primarily advocated selective caries removal for deep lesions,¹ the updated recommendations recognize that both selective and non-selective approaches may be appropriate depending on the clinical context. This change reflects the ongoing debate among professional organizations, as evidenced by differences in contemporary clinical practice guidelines.^{16,34,36,41,67-73} The most recent umbrella review by Aldakhil *et al.* concluded that no caries removal technique was consistently superior across all clinically relevant outcomes.⁷⁴ The overall certainty of the evidence was low to very low, with only two of the seven included systematic reviews rated as having moderate methodological quality. Although selective caries removal reduced the risk of pulp exposure, it did not consistently improve pulpal outcomes or prevent pulpal complications. In contrast, non-selective caries removal and stepwise excavation tended to demonstrate higher restorative success, while no significant differences were observed in dentine remineralization, tertiary dentine formation, or microbial reduction. Given the absence of high-certainty evidence demonstrating the long-term superiority of either approach, the choice of caries removal strategy should be individualized according to patient values and preferences, following an informed discussion of the risks and benefits, available resources (including calcium silicate cements and optical magnification), procedural invasiveness, treatment cost, local feasibility, and operator expertise. Within this framework, both selective and non-selective caries removal are considered biologically acceptable when appropriately adapted to the individual clinical situation.^{4,33,34,36-44,68} Given the limited long-term evidence currently available, however, these recommendations should be interpreted

with appropriate caution, and future guidelines may further refine preferred caries removal strategies as high-quality longitudinal data continue to emerge.

The rapidly ageing population, especially in Thailand, is expected to drive a corresponding rise in root caries prevalence, fueled by increased tooth retention, xerostomia secondary to polypharmacy, and diminished manual dexterity for oral hygiene maintenance. These factors collectively elevate caries risk and fundamentally shape management decisions.¹ The 9th National Oral Health Survey reported a high prevalence of untreated root caries and a low number of remaining teeth among older adults,⁷⁵ affecting their oral health-related quality of life. These findings indicate that primary prevention remains the most cost-effective strategy for caries management. In response, the management of root caries has evolved toward a risk-stratified, minimally invasive paradigm, as reflected in current evidence-based guidelines that integrate lesion activity, surface texture, and individual caries risk to guide clinical decision-making. Fluoride releasing agents, particularly 5% NaF varnish and 38% SDF solution, have emerged as cornerstone interventions,^{12,52,53,54} offering practical non-operative options that are especially valuable in the Thai geriatric and special care population where restorative feasibility is often limited by systemic conditions, polypharmacy-induced xerostomia, and access barriers.

With lesion progression to cavitation, minimally invasive restoration, particularly using mineral releasing-based materials, becomes the primary indicated approach, with fluoride releasing agents serving as adjuncts or alternatives when operative care is not feasible.^{53,54,56} Importantly, non-cleansable cavities necessitate recontouring or restoration to enable adequate plaque control, reinforcing the imperative for clinicians to integrate both preventive and restorative strategies within a patient-centered, special care dentistry framework.^{53-55,57} Rather than viewing these approaches as mutually exclusive, the proposed guidelines position them as complementary, with clinical decisions guided by lesion severity, patient capacity, and care setting. Ultimately, a commitment to evidence-informed practice will be

essential in ensuring that management strategies remain both clinically effective and contextually appropriate.

Conclusion

The 2026 Clinical Practice Guidelines for Carious Lesion Management provide an evidence-based framework for the diagnosis and management of carious lesions in primary and permanent dentitions. The updated recommendations reflect current scientific evidence and emphasize a minimally invasive, risk-based, and patient-centered approach that prioritizes disease prevention, preservation of tooth structure, and maintenance of pulp vitality. Key updates include enhanced use of fluoride-based preventive strategies, greater integration of radiographic findings into treatment planning, expanded management options for proximal and extensive lesions in primary teeth, recognition of both selective and non-selective carious tissue removal approaches for deep carious lesions in permanent teeth, and comprehensive guidance for root caries management in older adults.

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Case Report

Treatment of Multiple Cairo RT1 Gingival Recession Defects Using Vestibular Incision Subperiosteal Tunnel Access (VISTA) Technique with Subepithelial Connective Tissue Grafting: A 9-Month Follow-Up Case Report

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Abstract

Gingival recession is a common mucogingival condition associated with dentin hypersensitivity, root caries susceptibility, and esthetic concerns. Various periodontal plastic surgical procedures have been proposed for root coverage therapy. The Vestibular Incision Subperiosteal Tunnel Access (VISTA) technique is a minimally invasive approach designed to preserve papillary integrity and enhance vascular supply, thereby improving wound stability and esthetic outcomes. A 44-year-old systemically healthy Thai female patient presented with multiple gingival recession defects involving maxillary right lateral incisor to maxillary right first premolar. Clinical examination revealed Miller Class I and Cairo RT1 recession defects with baseline recession depths of 2.5 mm at maxillary right lateral incisor, 3.5 mm at maxillary right canine, and 1.5 mm at maxillary right first premolar. Root coverage surgery was performed using the VISTA technique in combination with subepithelial connective tissue grafting. Healing was uneventful throughout the postoperative period. At the nine-month follow-up, complete root coverage was achieved at maxillary right lateral incisor, whereas maxillary right canine and maxillary right first premolar demonstrated 85.7% and 66.7% root coverage, respectively. Improvement in keratinized tissue width, gingival thickness, clinical attachment level, and dentin hypersensitivity were observed. Favorable esthetic integration and stable soft tissue augmentation were maintained throughout the follow-up period. Within the limitations of this case report, the VISTA technique combined with subepithelial connective tissue grafting demonstrated favorable clinical and esthetic outcomes for the treatment of multiple Cairo RT1 gingival recession defects.

Keywords: Cairo RT1, Gingival recession, Root coverage, Subepithelial connective tissue grafting, VISTA technique

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Introduction

Gingival recession is characterized by the apical displacement of the gingival margin relative to the cemento-enamel junction (CEJ) resulting in exposure

of the root surface. It may occur in both localized and generalized forms and is frequently associated with dentin hypersensitivity, root caries susceptibility, plaque

retention, and esthetic concerns.¹ In 1992, Loe *et al.*² reported that populations aged 15-50 years occurred in greater than or equal to 60% of the 20 year-old, at 30 greater than or equal to 70% had recession which still was found mainly on buccal surfaces. As the group approached 50 years of age, more than 90% had gingival recession defects. In 2003, Kassab and Cohen¹ reviewed a paper that revealed that 88% of people 65 years and older and 50% of people 18 to 64 years of age have one or more sites with recession defects. In Thailand, Hosanguan *et al.*³ investigated gingival recession defects in Thai elderly 51-92 years, and revealed the percentage of sites with recession increased with age from 49.6% in 51-59 years to 72.0% in 70 years and older, and males exhibited greater levels of recession than females. Multiple etiologic factors have been implicated in the development of gingival recession defects including traumatic toothbrushing, periodontal inflammation, thin periodontal phenotype, tooth malposition, orthodontic tooth movement beyond the alveolar bone housing, subgingival restorative overhangs, and deleterious oral habits such as gingival picking with fingernails.⁴⁻⁶

P.D. Miller⁷ classified gingival recession defects into four categories based on the extent of marginal tissue recession and the degree of interdental bone and soft tissue loss as follows; Class I: Marginal tissue recession does not extend to the mucogingival junction without loss of interdental bone or papilla. Class II: Marginal tissue recession extends to the mucogingival junction without interdental bone or soft tissue loss. Class III: Marginal tissue recession extends to the mucogingival junction accompanied by partial loss of interdental bone and soft tissue. Class IV: Marginal tissue recession extends to the mucogingival junction with severe interdental bone and soft tissue loss extending apical to the level of the marginal recession. Complete root coverage can generally be anticipated in Miller Class I and II recession defects whereas only partial root coverage may be expected in Miller Class III defects. Miller Class IV defects are considered an unfavorable prognosis for root coverage procedures.⁷

In 2011, the American Academy of Periodontology adopted the classification proposed by Francesco Cairo *et al.*⁸ which categorizes gingival recession according to the interdental clinical attachment level as follows: Recession Type 1 (RT1): Gingival recession without interdental clinical attachment loss. This type demonstrates the highest predictability for complete root coverage. Recession Type 2 (RT2): Gingival recession associated with interdental clinical attachment loss in which the interdental attachment loss is less than or equal to the buccal attachment loss. Recession Type 3 (RT3): Gingival recession associated with interdental clinical attachment loss greater than the buccal attachment loss. This type demonstrates the least favorable prognosis for complete root coverage. In 2006, Zucchelli *et al.*⁹ revealed that predictability of successful root coverage largely depends on the remaining interdental bone support and the height of the interdental papilla. In 2001, Saletta *et al.*¹⁰ reported that greater interdental papillary height was positively associated with complete root coverage outcomes.

Various periodontal plastic surgical procedures have been proposed to achieve predictable root coverage and long-term soft tissue stability as follows.^{11,12}

1. Pedicle Soft Tissue Graft Procedures

1.1 Rotational flap procedures. These procedures include the lateral sliding flap and the double papilla flap techniques.^{13,14}

1.2 Advanced flap procedures include the coronally positioned flap and the semilunar coronally positioned flap.^{15,16}

2. Soft Tissue Graft Procedures involve harvesting donor tissue from another intraoral site. The palate and maxillary tuberosity are considered ideal donor sites because they provide sufficient tissue volume for the treatment of large recession defects or multiple adjacent recession sites. The palatal vault depth and gingival thickness significantly influence the amount of graft tissue that can be harvested.¹⁷

2.1 Free gingival graft (FGG) is a commonly performed procedure for increasing the width of attached gingiva because it is relatively simple and the donor site is easily accessible.¹⁸

2.2 Connective tissue graft procedures (CTG) include the subepithelial connective tissue graft, envelope technique, and tunnel technique. In 1985, Raul Langer and Bernard Langer¹⁹ introduced the subepithelial connective tissue graft technique for root coverage. This technique addressed several disadvantages associated with free gingival grafting by providing greater predictability of root coverage, improved esthetic integration with adjacent tissues and simultaneous augmentation of attached gingiva in both single and multiple recession defects. Subsequently, Raetzke²⁰ proposed the envelope technique for root coverage without vertical releasing incisions. The recipient site is prepared through the gingival sulcus to create a pouch-like space where the connective tissue graft is inserted. The advantages of the envelope technique are similar to those of conventional connective tissue grafting while eliminating vertical incisions and thereby minimizing postoperative scar formation. Consequently, this technique is particularly suitable for highly esthetic areas. Based on the tunnel technique in 1985, that originally was described by Raetzke²⁰ for isolated recession defects. In 1999, Zabalegui²¹ later introduced a modified tunnel technique for the treatment of multiple adjacent gingival recession defects. The recipient site is prepared similarly. The advantages are comparable to those of the envelope technique while enabling simultaneous treatment of multiple recession defects. Preparation of the recipient site without vertical releasing incisions preserves the vascular supply within the surgical area and enhances blood supply to the grafted tissue.²² However, the technique is highly technique-sensitive and precise adaptation and stabilization of the graft within the prepared tunnel require advanced surgical skills.

3. Regenerative approaches for root coverage include guided tissue regeneration (GTR), root coverage combined with enamel matrix derivative (EMD) and root coverage combined with acellular dermal matrix (ADM).

Among the various root coverage procedures currently available, the Vestibular Incision Subperiosteal Tunnel Access (VISTA) technique has emerged as a minimally invasive approach that preserves the marginal soft tissues and interdental papillae while allowing tension-free

coronal advancement of the gingival complex through a remote vestibular access incision. When combined with a subepithelial connective tissue graft, the technique has demonstrated predictable root coverage, increased keratinized tissue width and favorable esthetic outcomes.²³

Recent evidence has further strengthened the clinical application of the Vestibular Incision Subperiosteal Tunnel Access (VISTA) technique. A 2025 systematic review and meta-analysis by Zhu *et al.*²⁸ demonstrated that VISTA provides predictable root coverage, significant gains in clinical attachment level and keratinized tissue width, together with favorable esthetic outcomes and low postoperative morbidity. More recently, Tavelli *et al.*²⁹ reviewed the historical evolution of root coverage procedures and emphasized that minimally invasive approaches, including VISTA, represent an important milestone in contemporary periodontal plastic surgery because they preserve vascularity, minimize surgical trauma, and improve wound stability. Nevertheless, clinical outcomes remain influenced by several surgical and patient-related factors, highlighting the importance of reporting well-documented clinical cases with detailed descriptions of surgical execution and outcome assessment.

Case Report

A 44-year-old systemically healthy Thai female patient presented to the dental department of Pakthongchai Hospital, Nakhonratchasima with the chief complaint of gingival recession and dentin hypersensitivity in the maxillary right anterior region. Clinical examination revealed multiple gingival recession defects involving maxillary right lateral incisor to maxillary right first premolar teeth. The defects were classified as Miller Class I and Cairo RT1 recession defects. At baseline, recession depths were recorded as 2.5 mm at maxillary right lateral incisor, 3.5 mm at maxillary right canine, and 1.5 mm at maxillary right first premolar (Fig. 1). The recession defects were considered to be multifactorial in origin. Clinical examination demonstrated a thin periodontal phenotype with prominent root convexities affecting the maxillary anterior and premolar teeth. Cervical abrasion lesions were also present, suggesting a possible history of traumatic toothbrushing. There was

no evidence of active periodontal inflammation. Probing depths were within normal limits and no interdental clinical attachment loss was detected. Following comprehensive

periodontal examination, elimination of etiologic factors through oral hygiene instruction and plaque control was completed before surgical intervention.



Figure 1 Demonstrated Miller Class I and Cairo RT1 gingival recession defects on maxillary right lateral incisor to maxillary right first premolar and periapical radiographs of teeth 12, 13, 14

Surgical procedure

Following completion of initial periodontal therapy and oral hygiene reinforcement, root coverage surgery was performed using the VISTA technique combined with subepithelial connective tissue grafting. After administration of local anesthesia, a remote vestibular access incision was first created in the vestibule mucosa between the maxillary right canine and first premolar, approximately 5 mm apical to the gingival margin (Fig. 2a). The access incision was established initially to determine the surgical entry point, and facilitate subsequent instrumentation while preserving the integrity of the marginal gingiva and interdental papillae. Selective odontoplasty was then performed to reduce root prominence and facilitate passive coronal advancement of the gingival complex (Fig. 2b). Before preparation of the subperiosteal tunnel, the operative field was copiously irrigated with sterile saline to eliminate dentin debris generated during odontoplasty. A subepithelial connective tissue graft measuring approximately 15 mm × 7 mm, with a clinically estimated thickness of approximately 1.5 mm, was harvested from the right palate between the maxillary first premolar and first molar using the trap-door technique. The graft was carefully trimmed to fit the recipient site and inserted through the vestibular access incision into the prepared subperiosteal tunnel, ensuring complete adaptation over the exposed

root surfaces (Fig. 3). The gingival complex was then passively advanced coronally and stabilized using coronally anchored suspension sutures with Novasorb S 4-0 Polyglycolic acid. The suspension sutures were secured to the facial surfaces of the involved teeth using a light-cured flowable composite resin, thereby maintaining the gingival margin at the desired coronal position during the initial healing period. The vestibular access incision was subsequently approximated and closed with interrupted sutures (Fig. 4a). The palatal donor site was repositioned and secured with 4-0 silk sutures to achieve primary wound closure (Fig. 4b). Postoperative instructions included extrasoft toothbrushing, avoidance of flossing at the surgical site. Postoperative medications included amoxicillin 500 mg three times daily for five days, paracetamol 500 mg every 4-6 hours as needed for pain control, and 0.12% chlorhexidine gluconate mouth rinse twice daily for two weeks. Antibiotic therapy was prescribed because the procedure involved extensive subperiosteal tunnel preparation, placement of a subepithelial connective tissue graft, and the creation of both recipient and palatal donor surgical sites. The intention was to minimize the risk of postoperative wound contamination during the initial healing period. All sutures were removed at the nine-day postoperative visit.



Figure 2 a. vestibular incision b. odontoplasty c. subperiosteal tunnel



Figure 3 A SCTG harvested from the palate inserted through the prepared tunnel

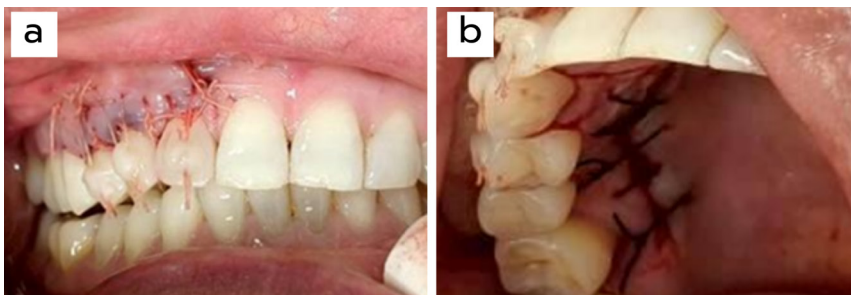


Figure 4 a. Coronally anchored suturing b. Donor site closure

Results

Postoperative healing was uneventful throughout the follow-up period. Clinical outcomes demonstrated significant improvement in gingival recession, clinical attachment level, keratinized tissue width, gingival thickness, and dentin hypersensitivity. At baseline, recession depths were 2.5 mm, 3.5 mm, and 1.5 mm at maxillary right lateral incisor, maxillary right canine and maxillary right first premolar, respectively. At the nine-month follow-up, recession depth was reduced to 0 mm at maxillary right lateral incisor, 0.5 mm at maxillary right canine and maxillary right first premolar. The percentage of root coverage achieved was 100% at maxillary right lateral incisor, 85.7% at maxillary right canine and 66.7% at maxillary right first premolar. Clinical attachment level

(CAL) improved from 4.5 mm to 1.5 mm at maxillary right lateral incisor, from 5.0 mm to 1.5 mm at maxillary right canine and from 2.5 mm to 1.5 mm at maxillary right first premolar. Keratinized tissue width increased from 3.0 mm to 4.0 mm at maxillary right lateral incisor, from 4.0 mm to 6.0 mm at maxillary right canine, and from 1.0 mm to 4.0 mm at maxillary right first premolar (Fig. 5a-5c). The patient also reported a substantial reduction in dentin hypersensitivity. Baseline VAS sensitivity scores of 5, 9, and 8 at maxillary right lateral incisor, maxillary right canine, and maxillary right first premolar, respectively, were reduced to 0 at all treated sites at the 9-month evaluation (Table 1).



Figure 5 a. Baseline b. 1-month evaluation c. 9-month evaluation

Table 1 Clinical parameters at Baseline, 1-Month and 9-Month evaluation

parameter	Baseline			1-month			9-month		
Tooth	12	13	14	12	13	14	12	13	14
Recession depth(mm)	2.5	3.5	1.5	0.5	1.0	0.5	0	0.5	0.5
PD(mm)	2.0	1.5	1.0	1.0	1.0	1.0	1.5	1.0	1.0
CAL(mm)	4.5	5.0	2.5	1.5	2.0	1.5	1.5	1.5	1.5
KT width(mm)	3.0	4.0	1.0	4.0	6.0	4.0	4.0	6.0	4.0
VAS sensitivity	5	9	8	0	2	0	0	0	0

Discussion

The treatment of multiple gingival recession defects remains one of the major challenges in periodontal plastic surgery because optimal outcomes require not only root coverage but also long-term soft tissue stability and favorable esthetic integration. Various surgical techniques have been proposed for root coverage procedures including coronally advanced flap (CAF), tunneling procedures and connective tissue grafting. In recent years, the Vestibular Incision Subperiosteal Tunnel Access (VISTA) technique that was originally introduced by Homa Zadeh²³ has gained increasing attention because of its minimally invasive design and ability to preserve vascular supply and papillary integrity. The etiology of gingival recession in the present patient was likely multifactorial. Clinical examination revealed a thin periodontal phenotype associated with prominent root convexities in the affected teeth, both of which have been recognized as predisposing anatomical factors for gingival recession. In addition, the presence of cervical abrasion suggested a history of traumatic tooth brushing, which may have contributed to the development and progression of the recession defects. These local anatomical and behavioral factors likely acted synergistically, resulting in multiple adjacent Cairo RT1 recession defects despite

the absence of interdental attachment loss. Recognition of these etiologic factors was important for treatment planning.

Several factors may have contributed to the favorable clinical outcome observed in the present case. Appropriate case selection and management of Cairo RT1 recession defects are fundamental prerequisites for predictable root coverage.⁸ In addition, adequate subperiosteal tunnel preparation and tension-free coronal advancement of the gingival complex are essential for minimizing flap tension, preserving vascular supply, and maintaining coronal flap stability during wound healing.^{23,29} Selective odontoplasty was performed to reduce root prominence and facilitate passive coronal positioning of the soft tissue. Furthermore, the use of a subepithelial connective tissue graft may have enhanced soft tissue thickness and improved long-term tissue stability,^{28,29} while coronally anchored suspension sutures secured with composite resin provided stable flap immobilization throughout the initial healing phase. Finally, the good plaque control by the patient and compliance with postoperative instructions and maintenance visits may also have contributed to the favorable healing and stable root coverage achieved in this case. The favorable clinical

outcomes observed in the present case are consistent with this biologic rationale. Complete root coverage was achieved at maxillary right lateral incisor, whereas maxillary right canine and maxillary right first premolar demonstrated substantial root coverage of 85.7% and 66.7%, respectively. Previous studies evaluating coronally advanced flap procedures combined with connective tissue grafts have reported mean root coverage ranging from approximately 70% to 95% depending on recession severity, tissue phenotype, and surgical technique.^{24,25} Aroca *et al.*²⁶ reported favorable long-term outcomes in the treatment of multiple adjacent gingival recessions defects using modified coronally advanced flap procedures combined with connective tissue grafting. The findings are also consistent with more recent evidence. Zhu *et al.*²⁸ conducted a systematic review and meta-analysis and concluded that the VISTA technique is a predictable treatment modality for gingival recession, demonstrating favorable root coverage, improvements in clinical attachment level, and increased keratinized tissue width with minimal postoperative morbidity. Similarly, Tavelli *et al.*²⁹ highlighted that the evolution of periodontal plastic surgery has progressively shifted toward minimally invasive techniques that emphasize preservation of vascular supply, flap stability, and periodontal phenotype enhancement rather than root coverage alone. The favorable outcomes observed in the present case support these contemporary concepts, particularly the achievement of substantial keratinized tissue gain, increased soft tissue thickness, and stable gingival margin positioning during the nine-month follow-up period.

Although the VISTA technique has been widely utilized for more than a decade, the present case emphasizes several technical considerations that may contribute to improved clinical outcomes. First, selective odontoplasty was performed to reduce excessive root convexity, thereby facilitating passive coronal advancement of the gingival complex and minimizing flap tension. Second, meticulous subperiosteal tunnel preparation combined with coronally anchored suspension sutures provided stable coronal positioning of the flap during the early healing phase. These modifications may have enhanced graft adaptation, preserved vascularity, and

promoted favorable soft tissue maturation. Compared with previously published reports using the VISTA technique in combination with subepithelial connective tissue grafts, the present case demonstrated not only predictable root coverage but also a marked increase in keratinized tissue width, particularly at the maxillary first premolar, where the keratinized tissue width increased from 1 mm to 4 mm. This finding is consistent with previous studies demonstrating that VISTA combined with connective tissue grafting promotes periodontal phenotype enhancement in addition to root coverage.^{23,28} Importantly, contemporary periodontal plastic surgery emphasizes that treatment success should not be evaluated solely by the percentage of root coverage but also by improvements in soft tissue phenotype, keratinized tissue dimensions, and long-term tissue stability, which are increasingly recognized as clinically meaningful outcome measures.²⁹

Connective tissue grafting remains the gold standard for periodontal root coverage procedures because of its predictable clinical performance and ability to enhance soft tissue thickness.²⁴ Increased gingival thickness is considered an important factor contributing to long-term stability of the gingival margin, resistance to mechanical trauma, and improved vascularity. In the present case, gingival thickness gain was observed at all treated sites, particularly at maxillary right canine, which demonstrated the greatest recession depth at baseline. Although complete root coverage was not achieved at this site, the increase in keratinized tissue and elimination of dentin hypersensitivity suggested clinically meaningful improvement. Similar observations have been reported in previous periodontal plastic surgery studies in which complete root coverage was not always necessary to achieve satisfactory patient-centered outcomes.²⁷ A limitation of the present case report is the relatively short follow-up period of nine months at the time of manuscript preparation. Although favorable clinical and esthetic outcomes were maintained throughout the observation period, longer-term follow-up is necessary to confirm the stability of root coverage, periodontal phenotype enhancement, and soft tissue maturation. The patient remains under supportive periodontal care, and continued clinical follow-up is planned to evaluate

the long-term stability of the treatment outcomes. Further randomized controlled clinical trials with larger sample sizes and long-term follow-up are necessary to validate the predictability and stability of this technique. The present case highlights that successful application of the VISTA technique depends not only on the surgical approach itself but also on meticulous execution of each procedural step and adherence to fundamental biological principles, including tension-free flap advancement, stable flap immobilization, soft tissue augmentation, and appropriate patient selection. These considerations may contribute to favorable clinical outcomes and should be regarded as important technical aspects when performing minimally invasive root coverage procedures.

Conclusion

Within the limitations of this case report, the Vestibular Incision Subperiosteal Tunnel Access (VISTA) technique combined with connective tissue grafting demonstrated favorable clinical and esthetic outcomes in the treatment of multiple Cairo RT1 gingival recession defects. Stable root coverage, increased keratinized tissue width, enhanced gingival thickness, improvement in clinical attachment level, and complete resolution of dentin hypersensitivity were maintained throughout the nine-month follow-up period. The favorable healing response and soft tissue stability observed in this case suggest that the VISTA technique may serve as a predictable minimally invasive approach for the management of multiple gingival recession defects in esthetically demanding regions.

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Knowledge and Denture Hygiene Behaviors among Removable Denture Wearers at Siriraj Hospital: A Cross-Sectional Study

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Abstract

This cross-sectional study aimed to assess knowledge and denture hygiene behaviors and to identify factors associated with overnight denture wearing among removable denture wearers attending the dental department of Siriraj Hospital. Overnight denture wearing was defined as the primary outcome, while denture storage method and use of effervescent denture-cleaning tablets were considered secondary outcomes. A total of 300 participants aged ≥ 25 years completed a structured questionnaire on demographic characteristics, knowledge of denture care, and hygiene practices. Associations between variables were analyzed using Chi-square or Fisher's exact tests, as appropriate, and factors associated with overnight denture wearing were further examined using binary logistic regression. Most participants were older adults (62% aged ≥ 65 years), and 59.3% had worn dentures for more than nine years. Limited knowledge regarding denture care was observed; 31% had never heard of effervescent denture-cleaning tablets, 24.3% reported using them, and only 8.3% were aware of the disadvantages of overnight denture wearing. Despite this, 82.3% reported removing dentures at night. Education level was significantly associated with the use of denture-cleaning tablets ($P = 0.029$). Duration of denture use ($P = 0.033$) and receipt of denture-care advice ($P = 0.040$) were associated with overnight denture wearing in univariable analyses but were not statistically significant after adjustment. These findings indicate limited knowledge but generally appropriate behaviors; as this was an exploratory study with multiple comparisons, results should be interpreted with caution, and reinforcement of denture-care education is recommended.

Keywords: Cross-sectional study, Denture care practices, Denture hygiene, Oral health knowledge, Removable dentures

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Introduction

The prevalence of prosthetic tooth wearers in Thailand has increased substantially with population aging. According to the 9th Thailand National Oral Health Survey (2022-2023), the prevalence of denture use is 3.9% among individuals aged 35–44 years, 21.8% among those aged

60–74 years, and 43.8% among those aged 80–85 years. Most prosthetic devices are removable dentures, and the demand for such prostheses is expected to increase in the future. However, many denture wearers present with inadequate denture hygiene during routine dental visits.¹

Wearing removable dentures is associated with increased plaque accumulation on denture surfaces.²⁻⁴ This facilitates the growth of oral microorganisms and contributes to various oral conditions, including denture stomatitis, gingivitis, periodontitis, and dental caries.³⁻⁷ In addition, these oral conditions have been linked to systemic diseases such as aspiration pneumonia, gastrointestinal infections, and bacterial endocarditis.^{3,6-10} Improper denture hygiene practices—such as inadequate cleaning, inappropriate cleaning methods, and prolonged denture wearing, particularly overnight—may further increase these risks.^{2,4,8} Maintaining proper denture hygiene and reinforcing appropriate behaviors are therefore essential components of oral and general health, especially among older adults.^{3,11,12}

Previous studies have demonstrated considerable variation in denture hygiene knowledge and practices across different populations. For example, a substantial proportion of denture wearers in several countries report inadequate cleaning practices or wearing dentures overnight.¹³⁻¹⁷ Cleaning methods also vary, including mechanical approaches (e.g., brushing) and chemical methods (e.g., effervescent denture-cleaning tablets), with differing levels of awareness and utilization among users.¹³⁻¹⁵ These findings suggest that both knowledge and behavior related to denture care are inconsistent and may be influenced by multiple factors.

Although national survey data indicate that a proportion of Thai denture wearers do not maintain adequate denture hygiene,¹ detailed evidence regarding knowledge and practices related to removable denture care, as well as the factors associated with these behaviors, remains limited in Thai clinical settings. Understanding these factors is important for developing targeted interventions to improve patient education and long-term adherence to appropriate denture-care practices.

Therefore, this study aimed to assess knowledge and denture hygiene behaviors and to identify factors associated with these behaviors, particularly overnight denture wearing, using both bivariate and multivariable analyses among removable denture wearers attending the Dental Department of Siriraj Hospital.

Materials and Methods

Study design and participants

This cross-sectional study was conducted among patients aged ≥ 25 years who had experience using removable dentures at the time of data collection. Participants were recruited from individuals attending the Dental Department of Siriraj Hospital, Bangkok, Thailand. A convenience sampling approach was used during the study period, which may limit the representativeness of the sample. Eligible participants were those able to communicate effectively and provide reliable responses. Individuals with cognitive or communication impairments that precluded reliable data collection were excluded.

Sample size

The required sample size for the logistic regression analysis was determined based on recommendations by Bujang *et al.*¹⁸ using the formula $n = 100 + 50i$, where i represents the number of independent variables. Given that five independent variables were pre-specified for consideration in the regression framework ($i = 5$), the minimum target sample size was calculated to be 350 participants.

Questionnaire development

Data were collected using a structured questionnaire developed for this study. The questionnaire comprised three sections: (1) demographic characteristics (gender, age, education level, and duration of denture use); (2) knowledge related to denture care, including awareness of cleaning methods and products; and (3) denture hygiene behaviors, including cleaning practices, use of effervescent denture-cleaning tablets, overnight denture wearing, and denture storage practices. Knowledge-related items were analyzed individually rather than as a composite score.

Validity and reliability

Content validity was evaluated by three experts in prosthodontics using the Content Validity Index (CVI), with all items achieving an Item-CVI and Scale-CVI of 1.0. A pilot study involving 30 participants was conducted to assess clarity and reliability. Test-retest reliability was evaluated using Cohen's kappa statistics, with values ranging from 0.772 to 1.0, indicating substantial to almost perfect agreement.

Data collection

Data were collected through face-to-face interviews conducted by a trained researcher using standardized procedures to ensure consistency and completeness of responses.

Study variables

The primary outcome was overnight denture wearing, categorized as yes/sometimes versus no. Participants reporting occasional overnight use were grouped with “yes” due to potential exposure to similar oral health risks. Secondary outcomes included denture storage method (dry versus soaking) and use of effervescent denture-cleaning tablets (yes/no).

Independent variables included gender, age, education level, duration of denture use, and receipt of denture-care advice from dentists. Age was treated as a continuous variable in the logistic regression analyses to enhance model parsimony and improve statistical stability. Education level was categorized as lower than bachelor’s degree, bachelor’s degree, and higher than bachelor’s degree. Duration of denture use was categorized as 0–3, >3–6, >6–9, and >9 years. Participants who were unable to recall whether they had received denture-care advice were excluded from analyses involving this variable to minimize potential misclassification bias.

Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize participant characteristics, knowledge, and denture hygiene behaviors. Categorical variables were presented as frequencies and percentages.

Associations between categorical variables were examined using the Pearson chi-square test. For contingency tables in which more than 20% of cells had expected counts less than 5, Fisher’s exact test (Fisher–Freeman–Halton extension) was applied to ensure valid inference. For significant overall associations in multi-category variables, post hoc pairwise comparisons were performed with Bonferroni correction to control for type I error within each set of comparisons. However,

no global adjustment across all statistical tests was performed, as the analyses were exploratory in nature.

For the primary outcome (overnight denture wearing), univariable logistic regression analyses were first conducted. Variables with $P < 0.10$ in univariable analyses or considered clinically relevant were included in the multivariable logistic regression model. All candidate variables were initially assessed; however, only variables meeting the predefined inclusion criteria were presented in the final model for clarity. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were reported.

Multicollinearity was assessed using variance inflation factors (VIFs). Model fit was evaluated using the Hosmer–Lemeshow goodness-of-fit test. A two-sided P -value < 0.05 was considered statistically significant.

A complete-case analysis approach was used. Participants with missing data were excluded from analyses involving the respective variables.

This study was approved by the Human Research Ethics Committee of the Faculty of Medicine Siriraj Hospital, Mahidol University (Approval No. 648/2563 [IRB4], October 20, 2020).

Results

A total of 300 participants were included in the study. Most participants were older adults, with 62% aged over 65 years, and 59.3% had been wearing dentures for more than 9 years (Table 1).

Regarding knowledge of denture care, a substantial proportion of participants demonstrated limited awareness. Approximately one-third (31.0%) had never heard of effervescent denture-cleaning tablets, and only 24.3% reported using them. In addition, only 8.3% of participants were aware of the disadvantages of overnight denture wearing. More than half of participants reported receiving denture-care advice from dentists, whereas most had not obtained such information from other sources.

In terms of denture hygiene behaviors, most participants (82.3%) reported removing their dentures during sleep, while 11.0% reported wearing them every night and 6.7% reported doing so occasionally. Toothbrushes

and toothpaste were the most commonly reported cleaning methods, and most participants who removed

their dentures at night reported storing them by soaking in water.

Table 1 Participant characteristics and denture care knowledge and behaviors (n = 300)

Variable	n (%)
General characteristics	
Gender	
Male	101 (33.7)
Female	199 (66.3)
Age group	
< 65 years	114 (38.0)
65 – 75 years	111 (37.0)
> 75 years	75 (25.0)
Education Level	
Lower than Bachelor's degree	140 (46.7)
Bachelor's degree	124 (41.3)
Higher than Bachelor's degree	36 (12.0)
Duration of denture use	
0 - 3 years	47 (15.7)
> 3 – 6 years	41 (13.7)
> 6 – 9 years	34 (11.3)
> 9 years	178 (59.3)
Knowledge regarding denture care	
Receiving advice for denture care from dentists, n=218 [†]	
Yes	127 (42.3)
No	91 (30.3)
Source of information regarding denture care	
Leaflets and documents	1 (0.3)
Television	11 (3.7)
Friends and relatives	11 (3.7)
Internet	9 (3.0)
Never	272 (90.7)
Source of information regarding effervescent denture-cleaning tablets (Can select more than one response)	
Do not recognize	93 (31.0)
Dentist	46 (15.3)
Television	101 (33.7)
Friends or relatives	42 (14.0)
Internet	3 (1.0)
Others (Drugstore)	15 (5.0)
Awareness of disadvantages of overnight denture wearing	
Yes	25 (8.3)
No	275 (91.7)
Denture hygiene behaviors	
Overnight denture wearing	
Yes	33 (11)
No	247 (82.3)
Occasionally	20 (6.7)
Denture cleaning methods (Can select more than one response)	
Water only	18 (6)
Toothbrush	276 (92)

Table 1 Participant characteristics and denture care knowledge and behaviors (n = 300) (cont.)

Variable	n (%)
Toothpaste	230 (76.7)
Sponge	2 (0.7)
Effervescent denture cleaning tablets	73 (24.3)
Soap	20 (6.7)
Dishwashing liquids	10 (3.3)
Mouthwash	2 (0.7)
Others (Baby Bottle Cleanser)	7 (2.3)
Overnight denture storage, n=267 [‡]	
Soaking in water	217 (72.3)
Dry	25 (8.3)
Soaking in mouthwash	6 (2.0)
Effervescent tablets	12 (4.0)
Others (Saline solution)	7 (2.3)

[†]Participants who could not remember whether they had received advice from dentists were excluded from analyses involving this variable.

[‡]Participants who wore overnight denture were excluded from analyses involving this variable.

No statistically significant associations were observed between denture storage methods and participant characteristics, including gender, age

group, education level, duration of denture use, and receipt of denture-care advice from dentists (Table 2).

Table 2 Factors associated with denture storage method among participants who did not wear dentures overnight (n = 267)

Variable	Overall (n = 267)	Overnight denture storage		p-value
		Dry storage (n=25)	Soaking storage (n=242)	
Gender, n (%)				1.000 ^a
Male	89 (33.3)	8 (32.0)	81 (33.5)	
Female	178 (66.7)	17 (68.0)	161 (66.5)	
Age group, n (%)				0.997 ^b
< 65 years	106 (39.7)	10 (40.0)	96 (39.7)	
65 – 75 years	98 (36.7)	9 (36.0)	89 (36.8)	
> 75 years	63 (23.6)	6 (24.0)	57 (23.6)	
Education Level, n (%)				0.970 ^c
Lower than Bachelor's degree	124 (46.4)	11 (44.0)	113 (46.7)	
Bachelor's degree	113 (42.3)	11 (44.0)	102 (42.1)	
Higher than Bachelor's degree	30 (11.2)	3 (12.0)	27 (11.2)	
Duration of denture use, n (%)				0.830 ^c
0 - 3 years	46 (17.2)	4 (16.0)	42 (17.4)	
> 3 – 6 years	38 (14.2)	5 (20.0)	33 (13.6)	
> 6 – 9 years	29 (10.9)	2 (8.0)	27 (11.2)	
> 9 years	154 (57.7)	14 (56.0)	140 (57.9)	
Receiving advice from dentists, n (%), n = 195 [†]				0.322 ^a
Yes	117 (60.0)	10 (47.6)	107 (61.5)	
No	78 (40.0)	11 (52.4)	67 (38.5)	

^a Yates' continuity correction

^b Pearson chi-square test

^c Fisher's exact test (Fisher-Freeman-Halton extension for rxc tables)

[†]Participants who could not remember whether they had received advice from dentists were excluded from analyses involving this variable.

Overall, 24.3% of participants reported using effervescent denture-cleaning tablets. In univariable analyses, education level was significantly associated with the use of these tablets ($P = 0.029$), whereas no statistically significant associations were found with gender, age group, duration of denture use, or receipt of denture-care advice from dentists (Table 3).

Logistic regression analysis was performed to further examine this association. As only education level met the inclusion criteria from the univariable analysis, a single-predictor logistic regression model was constructed.

The overall effect of education level on tablet use was statistically significant ($P = 0.032$). However, with participants who had postgraduate education (i.e., higher than a bachelor's degree) serving as the reference group, those with a bachelor's degree did not have significantly different odds of using effervescent denture-cleaning tablets (OR = 1.11; 95% CI: 0.48–2.52; $P = 0.811$). Similarly, participants with an education level lower than a bachelor's degree did not have significantly different odds of using effervescent denture-cleaning tablets compared with the reference group. (OR = 0.51; 95% CI: 0.22–1.20; $P = 0.124$).

Table 3 Association between participant characteristics and use of effervescent denture-cleaning tablets

Variable	Overall (n = 300)	The use of effervescent denture cleaning tablets		p-value
		Yes (n=70)	No (n=230)	
Gender, n (%)				0.143 ^a
Male	101 (33.7)	18 (25.7)	83 (36.1)	
Female	199 (66.3)	52 (74.3)	147 (63.9)	
Age group, n (%)				0.195 ^b
< 65 years	114 (38.0)	31 (44.3)	83 (36.1)	
65 – 75 years	111 (37.0)	27 (38.6)	84 (36.5)	
> 75 years	75 (25.0)	12 (17.1)	63 (27.4)	
Education Level, n (%)				0.029 ^{b*}
Lower than Bachelor's degree	140 (46.7)	23 (32.9)	117 (50.9)	
Bachelor's degree	124 (41.3)	37 (52.9)	87 (37.8)	
Higher than Bachelor's degree	36 (12.0)	10 (14.3)	26 (11.3)	
Duration of denture use, n (%)				0.883 ^b
0 – 3 years	47 (15.7)	12 (17.1)	35 (15.2)	
> 3 – 6 years	41 (13.7)	8 (11.4)	33 (14.3)	
> 6 – 9 years	34 (11.3)	9 (12.9)	25 (10.9)	
> 9 years	178 (59.3)	41 (58.6)	137 (59.6)	
Receiving advice from dentists, n (%), n = 218 [†]				0.473 ^b
Yes	127 (58.3)	36 (63.2)	91 (56.5)	
No	91 (41.7)	21 (36.8)	70 (43.5)	

* Significant at 0.05 level

^a Yates' continuity correction

^b Pearson chi-square test

[†] Participants who could not remember whether they had received advice from dentists were excluded from analyses involving this variable.

With respect to overnight denture wearing, duration of denture use ($P = 0.033$) and receipt of denture-care advice from dentists ($P = 0.040$) were associated with this behavior in univariable analyses (Table 4). Participants who had worn dentures for longer durations and those

who had not received professional advice tended to report a higher prevalence of overnight denture wearing. No statistically significant associations were observed with gender, age group, or education level.

Table 4 Association between participant characteristics and overnight denture wearing

Variable	Overall (n = 300)	Overnight denture wearing		p-value
		Yes /sometimes (n=54)	No (n=246)	
Gender, n (%)				0.829 ^a
Male	101 (33.7)	17 (31.5)	84 (34.1)	
Female	199 (66.3)	37 (68.5)	162 (65.9)	
Age group, n (%)				0.363 ^b
< 65 years	114 (38.0)	16 (29.6)	98 (39.8)	
65 – 75 years	111 (37.0)	22 (40.7)	89 (36.2)	
> 75 years	75 (25.0)	16 (29.6)	59 (24.0)	
Education Level, n (%)				0.306 ^b
Lower than Bachelor's degree	140 (46.7)	27 (50.0)	113 (45.9)	
Bachelor's degree	124 (41.3)	18 (33.3)	106 (43.1)	
Higher than Bachelor's degree	36 (12.0)	9 (16.7)	27 (11.0)	
Duration of denture use, n (%)				0.033 ^{b*}
0 – 3 years	47 (15.7)	3 (5.6)	44 (17.9)	
> 3 – 6 years	41 (13.7)	4 (7.4)	37 (15.0)	
> 6 – 9 years	34 (11.3)	8 (14.8)	26 (10.6)	
> 9 years	178 (59.3)	39 (72.2)	139 (56.5)	
Receiving advice from dentists, n (%), n = 218 [†]				0.040 ^{b*}
Yes	127 (58.3)	17 (43.6)	110 (61.5)	
No	91 (41.7)	22 (56.4)	69 (38.5)	

* Significant at 0.05 level

^a Yates' continuity correction^b Pearson chi-square test[†]Participants who could not remember whether they had received advice from dentists were excluded from analyses involving this variable.

Variables with $P < 0.10$ in univariable analysis were included in the multivariable logistic regression model. All candidate variables were initially entered into the multivariable model; however, only variables meeting the predefined criteria are presented for clarity.

In the univariable analysis, duration of denture use was significantly associated with overnight denture wearing ($P = 0.049$). Compared with participants who had worn dentures for 0–3 years, those with 6–9 years and more than 9 years of denture use had significantly higher odds of overnight denture wearing (OR = 4.513; 95% CI: 1.099–18.534; $P = 0.037$ and OR = 4.115; 95% CI: 1.212–13.970; $P = 0.024$, respectively), while no significant association was observed for those with 3–6 years of denture use.

After adjustment in the multivariable logistic regression model, duration of denture use remained associated with overnight denture wearing. Compared with participants who had worn dentures for 0–3 years, those with more than 9 years of denture use had significantly higher odds of overnight denture wearing (adjusted OR = 5.553; 95% CI: 1.260–24.480; $P = 0.024$). Participants with 6–9 years of denture use also showed higher odds, although this did not reach statistical significance (adjusted OR = 5.294; 95% CI: 0.931–30.111; $P = 0.060$). In contrast, no statistically significant association was observed among participants with 3–6 years of denture use. (Table 5).

No evidence of multicollinearity was observed ($VIF \approx 1$), and the Hosmer–Lemeshow goodness-of-fit test indicated that the model had an adequate fit ($P = 0.336$).

Table 5 Univariable and multivariable logistic regression analyses of factors associated with overnight denture wearing (n = 218)

Variable	Unadjusted OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value	VIF
Duration of denture use					
0–3 years	Reference		Reference		
>3–6 years	1.586 (0.333–7.542)	0.562	1.687 (0.265–10.748)	0.580	1.011
>6–9 years	4.513 (1.099–18.534)	0.037*	5.294 (0.931–30.111)	0.060	
>9 years	4.115 (1.212–13.970)	0.024*	5.553 (1.260–24.480)	0.024*	
Receiving advice from dentists					
Yes	Reference		Reference		
No	2.063 (1.024–4.158)	0.043*	1.551 (0.743–3.235)	0.242	1.032

*Significant at $P < 0.05$

VIF = Variance inflation factor

Discussion

The findings of this study indicate that removable denture wearers attending the Dental Department of Siriraj Hospital demonstrated limited knowledge regarding appropriate denture-care practices. A substantial proportion of participants were unaware of recommended cleaning methods and the potential risks associated with overnight denture wearing. These findings are consistent with previous studies conducted in other countries, which have reported inadequate patient knowledge and suboptimal denture hygiene practices among denture wearers.^{14,15}

Despite the limited knowledge observed, most participants reported appropriate denture hygiene behaviors, particularly removing their dentures during sleep. This discrepancy between knowledge and behavior may suggest that denture-care practices are influenced more by habitual behaviors or prior clinical instructions than by retained knowledge. It is also possible that patients follow instructions provided at the time of denture delivery without fully understanding the underlying rationale.^{15,17,19} This finding highlights the importance of reinforcing denture-care education during recall visits to support long-term adherence.

More than half of participants reported receiving denture-care advice from dentists, while only a small proportion reported obtaining such information from other sources. Although dentists may be an important source of denture-care information, the present study did not find statistically significant differences in several

denture hygiene behaviors between participants who reported receiving advice and those who did not. However, in univariable analysis, participants who had not received professional advice were more likely to report overnight denture wearing. This association was attenuated and no longer statistically significant after adjustment in the multivariable model, suggesting that the observed relationship may be influenced by other measured or unmeasured factors.

Similarly, the duration of denture use was associated with overnight denture wearing in the univariable analysis, with longer duration linked to a higher likelihood of this behavior. After adjustment, participants with more than 9 years of denture use had significantly higher odds of overnight denture wearing, whereas other duration categories were not statistically significant. The observed trend may reflect behavioral changes over time, such as reduced adherence to initial instructions or diminished recall of denture-care recommendations.^{20,21} In addition, the relationship between duration of denture use and overnight denture wearing may be subject to residual confounding arising from unmeasured or imprecisely measured factors. This potential limitation should be considered when interpreting these findings.

In terms of denture cleaning practices, most participants reported using a toothbrush and toothpaste, which is consistent with findings from previous studies.^{13,15} However, the use of toothpaste may increase surface

abrasion and roughness of denture materials.^{22,23} Current guidelines recommend the use of non-abrasive cleaning agents in combination with mechanical cleaning.²³ Although the use of effervescent denture-cleaning tablets has been shown to improve denture hygiene, only a minority of participants reported using these products.^{23,24} Regarding chemical denture hygiene practices, education level demonstrated an overall association with the use of effervescent denture-cleaning tablets. However, pairwise comparisons using postgraduate education as the reference category did not reveal statistically significant differences between individual educational groups. These findings suggest that factors beyond formal educational attainment, such as awareness of product availability, clinician recommendations, or financial considerations, may also influence the adoption of commercial denture-cleansing products.

Regarding denture storage practices, most participants reported soaking their dentures in water overnight. This practice is generally consistent with current recommendations to prevent distortion of denture materials.²³ However, some variation in practice was observed, and the evidence regarding optimal storage conditions remains limited, indicating a need for further research in this area.^{24,25}

This study has several limitations. First, the cross-sectional design does not allow causal relationships to be established. Second, data were collected using self-reported questionnaires, which may be subject to recall bias and social desirability bias. Third, multiple statistical comparisons were conducted without formal adjustment for multiplicity, as this study was exploratory in nature. Therefore, the reported *P*-values should be interpreted with caution, and the possibility of type I error cannot be excluded. Only 300 participants were available for analysis, which was below the minimum target sample size of 350 recommended by Bujang *et al.*¹⁸ This shortfall may have reduced the precision of the regression estimates and increased the risk of type II error; therefore, the regression findings should be interpreted with caution.

Despite these limitations, this study provides valuable information regarding denture-care knowledge and practices among removable denture wearers in

Thai clinical settings. The findings highlight the need for improved patient education and the reinforcement of denture-care instructions during follow-up visits to promote appropriate denture hygiene practices.

Conclusions

Removable denture wearers demonstrated limited knowledge regarding appropriate denture hygiene practices, although most reported appropriate behaviors such as removing dentures during sleep. While certain factors, including duration of denture use and receipt of denture-care advice from dentists, were associated with overnight denture wearing in univariable analyses, these associations were not statistically significant after adjustment in the multivariable model. The findings highlight the importance of reinforcing denture-care instructions and promoting continuous patient education during follow-up visits to support appropriate denture hygiene practices and improve long-term oral health outcomes.

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Determinants of Oral Health Literacy Among Filipino Schoolchildren: An Information-Motivation-Behavioral Skills Model Approach

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Abstract

This study aimed to identify determinants of the oral health literacy (OHL) related to dental caries using the Information, Motivation and Behavioral Skills (IMB) model among Filipino schoolchildren. A cross-sectional study was conducted among 274 schoolchildren aged 9-13 years from six public elementary schools in Baguio City, Philippines. Data were collected using validated self-administered questionnaires assessing OHL and the IMB constructs. Clinical examinations were performed to assess dental caries using the DMFT/dmft indices and oral hygiene using the Simplified Debris Index (DI-S). Descriptive statistics, Pearson's correlation, and univariate and multivariate linear regression analyses were performed. Among the participants, 58.8% were female, with a mean age of 10.55 (SD = 0.68) years. The mean DI-S score was 1.50 (SD = 0.69), while the mean dmft and DMFT scores were 1.68 (SD = 2.27) and 4.61 (SD = 3.18), respectively. The mean OHL score was 19.54 (SD = 3.62). No significant associations were observed between oral health status (DMFT, dmft, or DI-S) and OHL or the IMB constructs. However, a weak positive correlation was found between dmft and DI-S ($r = 0.132, p = 0.029$). In the multivariable regression model, maternal education ($\beta = 0.212, p < 0.001$), information ($\beta = 0.211, p < 0.001$), social motivation ($\beta = 0.213, p = 0.003$), and behavioral skills ($\beta = 0.197, p = 0.002$) were significant predictors of OHL after adjustment for personal motivation, DI-S, and dmft. These variables explained 36.9% of the variance in OHL scores ($R^2_{adj} = 0.369$). These findings highlight the importance of maternal education, oral health information, social motivation, and behavioral skills in improving oral health literacy among schoolchildren and support the development of theory-driven interventions to strengthen oral health behaviors.

Keywords: Dental Caries, Determinants, Information-Motivation-Behavioral Skills Model, Oral Health Literacy, Schoolchildren

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Introduction

Oral health is a fundamental component of overall health and well-being, encompassing the ability to

speak, smile, chew, and function without pain or disease of the craniofacial complex.¹ It reflects a dynamic interplay

of physiological, psychological, and social factors that evolve across the life course and significantly influence quality of life and societal participation.² Oral health changes throughout life, from childhood to old age. It is integral to general health and enables individuals to engage in society and reach their potential.³

Despite being largely preventable, oral diseases, particularly dental caries, remain a major global public health challenge. An estimated 514 million children worldwide are affected by dental caries in their primary teeth, underscoring the urgent need for effective preventive strategies.⁴ Dental caries is still a neglected topic, despite the acknowledgment of the WHO that it is still a major health problem in most industrialized countries, in which 60–90% of children and the vast majority of adults are affected by dental caries.⁵ Oral diseases also contribute substantially to disability-adjusted life years (DALYs), highlighting their long-term health and economic consequences.⁶ Marked disparities persist, with children from socioeconomically disadvantaged backgrounds experiencing higher caries prevalence and unmet treatment needs, emphasizing the role of social determinants of health.^{4,6-9} This inequity underscores the importance of addressing social determinants of health as part of comprehensive oral health strategies.^{8,10,11} In the Philippines, national data indicate a high burden of disease, with an 83% prevalence of dental caries among children, reflecting a severe public health concern.¹²

While poor oral hygiene has traditionally been identified as a key etiological factor through plaque accumulation and acid production,¹³⁻¹⁵ dental caries is now widely recognized as a multifactorial condition influenced by behavioral, environmental, and social factors. Among these, oral health literacy (OHL) and oral health behaviors play critical roles in shaping oral health outcomes. Evidence suggests that limited OHL is associated with inadequate knowledge, suboptimal hygiene practices, and increased caries risk, while behaviors such as frequent sugar intake and inconsistent toothbrushing further exacerbate disease progression.^{16,17} Moreover, family support and broader social influences significantly affect the ability of children to adopt and sustain healthy oral health

practices. These complexities highlight the limitations of traditional oral health education approaches that focus solely on hygiene practices. Instead, there is a growing need for comprehensive, theory-driven strategies that integrate knowledge, motivation, and behavioral skills. Understanding the relationship between dental caries, oral health literacy, and oral health behavior is therefore essential for informing targeted, equitable, and sustainable public health interventions among schoolchildren. This study aimed to assess baseline oral health status, oral health literacy and behaviors among Filipino schoolchildren, and to examine their association with dental caries. These findings are intended to inform the development of a culturally appropriate, digital IMB-based oral health intervention program.

Materials and Methods

Study Design and Participants

A cross-sectional baseline study was conducted among Grades 5 and 6 schoolchildren in six public elementary schools in Baguio City, Philippines. The study utilized a two-stage sampling design. First, schools were selected through convenience sampling based on administrative approval and logistical accessibility. These participating schools were located in urban and semi-urban areas, serving students from diverse socioeconomic backgrounds typical of government-funded schools in the study setting.

Second, the recruitment process and participant flow across the six study sites were determined using probability proportional to size (PPS) stratified random sampling to ensure fair representation (Table 1). A total of 1,324 students were eligible across the three urban and three semi-urban elementary schools. Out of these, 290 students were randomly selected, all of whom completed the baseline questionnaire (100% initial participation). Following data cleaning, 16 students were excluded due to incomplete surveys ($n=10$), unrealistic or conflicting answers ($n=4$), and falling outside the target age ($n=2$), leaving a final sample of 274 students. The overall response rate was 94.5%, remaining highly consistent across individual schools, ranging from 93.8% (School 3) to 95.5% (School 6).

Eligibility criteria included: (1) current enrollment in Grade 5 or Grade 6, and (2) provision of written informed consent from a parent or legal guardian along with written assent from the child. Exclusion criteria comprised: (1) ongoing orthodontic treatment, (2) presence of advanced oral disease requiring urgent dental care, (3) serious medical conditions that could interfere with participation, and (4)

visual or hearing impairments that could limit the ability to complete study procedures.

The study adhered to the ethical principles outlined in the Declaration of Helsinki and received approval from the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2025-015).

Table 1 Recruitment of participants across participating schools

School	Location	Eligible Students (N)	Randomly Selected (n)	Completed Baseline Survey (n)	Excluded* (n)	Final Sample (n)	School Response Rate (%)
School 1	Urban	242	53	53	3	50	94.3%
School 2	Urban	94	21	21	1	20	95.2%
School 3	Urban	147	32	32	2	30	93.8%
School 4	Semi-Urban	149	33	33	2	31	93.9%
School 5	Semi-Urban	489	107	107	6	101	94.4%
School 6	Semi-urban	203	44	44	2	42	95.5%
Total	—	1,324	290	290	16	274	94.5% (Overall)

*Note: Reasons for exclusion included incomplete surveys (n=10), invalid or conflicting response patterns (n=4), and age outliers (n=2).

Sample Size Calculation

The required sample size was determined using G*Power software (version 3.1.9.7). Because no prior studies in a comparable population reported effect sizes for oral health literacy, a conservative small effect size (Cohen’s d = 0.20) was assumed.¹⁸ A two-tailed one-sample t-test with $\alpha = 0.05$ and 90% power yielded a required sample size of 265 participants.

For the multiple linear regression analysis, the parameters were as follows: Test family: F tests; Statistical test: Linear multiple regression: Fixed model, R^2 deviation from zero; Type of power analysis: A Priori: Compute required sample size- given α , power, and effect size; Input parameters: effect size =0.15; α error probability = 0.05; Power =0.95; Number of predictors = 20. G*Power recommended a total sample size of 222 for this analysis.

The larger estimate of 265 participants was adopted as the primary target. To account for potential non-response, missing data, or exclusions during data cleaning, the recruitment target was increased, resulting in 290 participants being initially selected.

Data Collection

Data was collected between May and July 2025. After data cleaning, 274 complete responses were included in the analysis.

Questionnaire Assessment

Data on sociodemographic factors and oral health literacy were collected using a validated, self-administered questionnaire. The questionnaire was pilot-tested for comprehension with ten school children who were similar but not part of the study, confirming that there were no incomprehensible questions.

Sociodemographic data collected included the age and gender of the child, the age, education level, and occupation of their parents and family monthly income (Low income - less than PHP 24,060 per month; Middle income – between PHP 24,060-PHP 144,360 per month; and High income – above PHP 144,360).¹⁹

Oral health literacy was assessed using a 29-item instrument adapted from the oral health literacy questionnaire developed by Acosta and Pisarnturakit²⁰ covering key domains, including: (1) structure and function of the teeth

and oral cavity, (2) dental caries and periodontal disease, (3) preventive practices, (4) oral hygiene practices such as toothbrushing, and (5) dietary factors and nutrition. Each item was scored dichotomously (1 = correct; 0 = incorrect or “don’t know”), with higher total scores indicating greater knowledge. The instrument demonstrated good psychometric properties, with satisfactory internal consistency (Cronbach's $\alpha = 0.804$) and excellent test–retest reliability (intraclass correlation coefficient [ICC] = 0.898), supporting its reliability for use among schoolchildren.

The Information-Motivation-Behavioral Skills (IMB) constructs were evaluated using the Information–Motivation–Behavioral Skills Oral Health Behavior Questionnaire for Schoolchildren (IMB-OHBQ-SC), developed and validated by Acosta and Pisarniturakit.²⁰ The questionnaire comprises three domains: Information (five items related to oral hygiene practices), Motivation (17 items assessing personal attitudes [seven items] and perceived social support [ten items]), and Behavioral Skills (six items evaluating tooth brushing self-efficacy). Responses were recorded on a three-point Likert scale (1 = disagree, 2 = neutral, 3 = agree), with higher scores reflecting more favorable behavioral determinants. The questionnaire demonstrated satisfactory content validity (mean Item–Objective Congruence [IOC] = 0.88), construct validity through exploratory factor analysis supporting the three-factor IMB structure (KMO = 0.795; Bartlett's test, $p < 0.001$), good internal consistency (Cronbach's $\alpha = 0.88$ overall; subscales: 0.80–0.84), and good test–retest reliability (ICC = 0.77–0.81), indicating satisfactory psychometric properties for assessing IMB constructs among schoolchildren.

Clinical Oral Examination

Clinical examinations were conducted by two trained and calibrated dental students and one dentist following standardized examination protocols. Prior to data collection, all examiners underwent theoretical and practical training and calibration with 30 Grade 5 and 6 schoolchildren. Intra-examiner reliability was assessed through repeated examinations conducted one week apart, while inter-examiner reliability was evaluated by independent examinations of the same participants. Excellent inter-examiner agreement was achieved for oral hygiene assessment using the Simplified Debris Index (DI-S) (intraclass correlation coefficient [ICC] = 0.961 for single

measures and 0.980 for average measures; $p < 0.001$). Dental caries assessment also demonstrated high reliability, with kappa values of 0.80 for inter-examiner agreement and 1.00 for intra-examiner agreement.

Oral hygiene status was evaluated using the Simplified Debris Index (DI-S). Dental plaque was disclosed using erythrosine dye, and each tooth surface was scored from 0 to 3, where 0 indicates no plaque; 1 indicates plaque covering $\leq 1/3$ of the tooth surface; 2 indicates plaque covering $>1/3$ to $<2/3$; and 3 indicates plaque covering $>2/3$ of the tooth surface. Individual scores were averaged and categorized as good (0.1–0.6), fair (0.7–1.8), or poor (1.9–3.0) oral hygiene.²¹ Dental caries experience was assessed using the Decayed, Missing, and Filled Teeth indices for permanent (DMFT) and primary dentition (dmft), following World Health Organization standard criteria.²² Because children aged 9–13 years are typically in the mixed dentition stage, both the DMFT and dmft indices were included to capture caries experience in the permanent and retained primary teeth.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 29. Descriptive statistics, including means, standard deviations (SD), frequencies, and percentages, were employed to summarize participant characteristics, questionnaire responses, and clinical findings. Bivariate analyses included t-test, one-way ANOVA, and Pearson's correlation.

Multiple linear regression was conducted to identify factors associated with oral health literacy. Variables with a p -value < 0.20 in simple linear regression were selected as candidates for analysis. A stepwise regression approach was used as an exploratory screening method, followed by the enter method to incorporate additional dummy variables and key confounders based on theoretical considerations. All questionnaires were checked in the field, and no missing data were found.

Before interpreting the regression model, the assumptions of regression were evaluated. Linearity and homoscedasticity were assessed using residual scatterplots, while the normality of the residuals was examined through histogram and P-P plots. Multicollinearity was examined using variance inflation factors (VIF), which were all below 2, indicating no evidence of multicollinearity among the

predictor variables. Regression diagnostics aimed at detecting outlier, high-leverage points, and influential observations were employed to test the model sensitivity. This involved examining standardized residuals, leverage (hat values), and Cook's distance. Additionally, additional analyses were conducted to assess the stability of the regression estimates.

Results

The sociodemographic characteristics of the 274 participants are detailed in Table 2. The average age of the children was 10.55 years (SD: 0.678), with most

children falling within the 10–11 year age range. Among the students, 58% were female. The average age of the mothers and fathers were 37.12 years (SD:6.455) and 40.12 years (SD:8.296), respectively, with the majority of parents in the 30–49-year age group. In terms of educational attainment, most mothers and fathers had completed college or higher education, followed by those who had at least a high school diploma. Regarding occupation, a significant number of mothers were stay-at-home caregivers, while most fathers were either employed or self-employed. Additionally, the majority of families were classified as low-income.

Table 2 Sociodemographic characteristics of participants (n=274)

Variable	N	%	Mean	SD	Min	Max
Child's Age (years)			10.55	0.678	9	13
9	7	2.55				
10	122	44.53				
11	128	46.72				
12, 13	17	6.2				
Child's Gender						
Male	113	41.24				
Female	161	58.76				
Mother's Age (years)			37.12	6.455	26	58
20-29	28	10.22				
30-39	139	50.73				
40-49	88	32.12				
50-59	9	3.28				
Undisclosed	10	3.65				
Father's Age (years)			40.12	8.296	27	77
20-29	9	3.28				
30-39	119	43.43				
40-49	91	33.21				
50-69	32	11.68				
70-77	23	8.39				
Undisclosed	23	8.33				
Mother's education						
College/undergraduate or above	150	54.74				
≥High school	98	35.77				
≥ Elementary	14	5.11				
Undisclosed	12	4.38				
Father's education						
College/undergraduate or above	134	48.91				
≥High school	100	36.5				
≥ Elementary	17	6.2				
Undisclosed	23	8.39				

Table 2 Sociodemographic characteristics of participants (n=274) (cont.)

Variable	N	%	Mean	SD	Min	Max
Mother's occupation						
Employee	81	29.56				
Self-employed	63	22.99				
Unemployed	19	6.93				
Stay-at-home mom	101	36.86				
Undisclosed	10	3.65				
Father's occupation						
Employee	125	45.62				
Self-employed	100	36.5				
Unemployed	17	6.2				
Retired	10	3.65				
Undisclosed	22	8.03				
Family monthly income						
Low income	190	69.34				
Middle income	66	24.09				
High income	3	1.09				
Undisclosed	15	5.47				

For the oral hygiene status, DI-S ranged from 0 to three with an average of 1.50 (SD:0.69). The children had an average dmft score of 1.68 (SD:2.27), with values ranging from 0 to 11; the average DMFT score was 4.61 (SD:3.18), ranging from 0 to 17. The average total OHL

score was 19.54 (SD:3.62), with scores ranging from 6 to 28. The average score for the IMB constructs were as follows: information 14.05 (SD:1.55); personal motivation 20.32 (SD:1.35); social motivation 28.51 (SD:2.53); and behavioral skills 17.19 (SD:1.46). Further details can be found in Table 3.

Table 3 Descriptive statistics of oral health status, oral health literacy, and IMB constructs (n=274)

Variable	Mean	SD	Min	Max
DI-S	1.50	0.69	0	3
dmft	1.68	2.27	0	11
DMFT	4.61	3.18	0	17
OHL Total	19.54	3.62	6	28
OHL about Teeth	2.05	0.73	0	3
OHL about Dental Caries	6.57	1.46	1	9
OHL Preventive practices	5.23	1.46	0	7
OHL Toothbrushing	2.61	0.8	0	4
OHL Dietary behavior	3.07	1.09	0	6
Information	14.05	1.55	6	15
Personal Motivation	20.32	1.35	14	21
Social Motivation	28.51	2.53	14	30
Behavioral Skills	17.19	1.46	12	18

Table 4 shows that neither oral hygiene status (DI-S) nor dental caries experience (DMFT and dmft) was significantly associated with the total oral health

literacy (OHL) score or the IMB constructs (information, personal motivation, social motivation, and behavioral skills) (all $p > 0.05$). However, a weak but statistically

significant positive correlation was observed between dmft scores and DI-S ($r = 0.132$, $p = 0.029$), indicating that poorer oral hygiene was associated with greater dental caries experience in the primary dentition. Significant positive correlations were also observed

between the OHL total score and all IMB constructs, as well as among the IMB constructs themselves (all $p < 0.001$), supporting the relationships proposed by the IMB theoretical framework.

Table 4 Correlation between dental caries (DMFT and dmft), oral health literacy, and IMB constructs (N=274)

	DI-S	dmft	DMFT	OHL Total	Information	Personal motivation	Social motivation	Behavioral skills
DI-S	1							
dmft	0.132*	1						
DMFT	0.023	-0.233**	1					
OHL Total	0.001	-0.079	0.007	1				
Information	0.051	0.077	-0.054	0.435**	1			
Personal motivation	0.024	0.085	0.002	0.411**	0.443**	1		
Social motivation	-0.033	-0.065	-0.005	0.501**	0.454**	0.636**	1	
Behavioral skills	-0.044	-0.078	0.025	0.482**	0.422**	0.530**	0.629**	1

Note: * $p < 0.05$, ** $p < 0.01$ (2-tailed)

Bivariate analyses indicated that the education level of both mothers and fathers, along with the IMB constructs (information, personal motivation, social motivation and behavioral skills), were significantly associated with OHL total scores (Table 5). No significant associations were observed between oral hygiene status (DI-S), dental caries experience (DMFT or dmft), and OHL total scores.

In the multivariable regression model, maternal education and the IMB constructs of information, social motivation, and behavioral skills remained significant predictors of OHL after adjustment for personal motivation, oral hygiene status (DI-S), and dental caries experience (dmft). These variables explained 36.9% of the variance in OHL scores ($R^2_{adj} = 0.369$; $F = 23.781$, $p < 0.001$). Significant predictors included social motivation ($\beta = 0.213$, $p = 0.003$), maternal education ($\beta = 0.212$, $p < 0.001$), information ($\beta = 0.211$, $p < 0.001$), and behavioral skills ($\beta = 0.197$, $p = 0.002$). The regression coefficients are presented in Figure 1A.

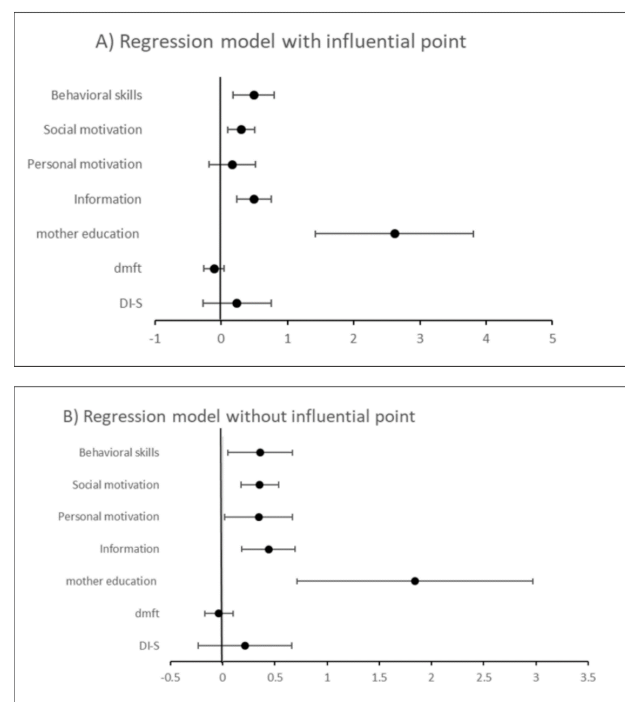


Figure 1 Forest plot of unstandardized beta coefficient (B) of the regression model on the OHL total score with (A; $n=274$) and without (B; $n=256$) influential point

Table 5 Univariate, multivariate linear regression analysis and sensitivity analysis on oral health literacy score

	Univariate Linear Regression				Multivariate Linear Regression				Sensitivity analysis			
	B	Beta	t	p-value	B	Beta	t	p-value	B	Beta	t	p-value
Child's Gender	0.762	0.104	1.721	0.086								
Child's age (yrs)	-0.282	-0.053	-0.876	0.382								
Mother's age (yrs)	0.018	0.032	0.522	0.602								
Father's age (yrs)	0.02	0.044	0.72	0.472								
Mother education	3.482	0.282	4.852	<.001	2.618	0.212	4.324	<.001	1.843	0.158	3.217	0.001
Father education	1.799	0.176	2.943	0.004								
Mother job	0.333	0.046	0.759	0.448								
Father job	0.504	0.053	0.883	0.378								
DI-S	0.006	0.001	0.019	0.984	0.239	0.045	0.921	0.358	0.213	0.046	0.932	0.352
dmft	-0.126	-0.079	-1.307	0.192	-0.108	-0.067	-1.359	0.175	-0.038	-0.027	-0.553	0.581
DMFT	0.008	0.007	0.117	0.907								
Information	1.019	0.435	7.968	<.001	0.493	0.211	3.728	<.001	0.44	0.192	3.384	0.001
Personal motivation	1.106	0.411	7.427	<.001	0.17	0.063	0.96	0.338	0.344	0.139	2.069	0.04
Social motivation	0.718	0.501	9.558	<.001	0.305	0.213	2.998	0.003	0.354	0.274	3.905	<.001
Behavioral Skills	1.199	0.482	9.076	<.001	0.491	0.197	3.056	0.002	0.359	0.155	2.286	0.023
Constant					-10.535		-3.76	<.001	-11.688		-4.587	<.001
n	274				274				256			
R ²					0.385				0.429			
R ² _{adj}					0.369				0.413			
SS Regression					1378.862	df=7			1072.198	df=7		
SS Residual					2203.273	df=266			1428.017	df=248		
SS Total					3582.135	df=273			2500.215	df=255		
F					23.781				26.601			
p-value					<.001				<.001			

Note: Sensitivity analysis was performed after excluding influential observations (n = 256). The observations were identified using regression diagnostic criteria, including studentized residuals exceeding ± 3 , high leverage values, and influence diagnostics (Cook's distance), indicating undue influence on parameter estimates.

Regression diagnostics identified one influential observation based on studentized residuals, leverage values, and Cook's distance. A sensitivity analysis conducted after excluding this observation demonstrated improved model fit ($R^2_{adj} = 0.413$; $F = 26.601$, $p < 0.001$). The overall pattern of results remained consistent, although personal motivation became a significant predictor. In the adjusted model, significant predictors of OHL included social motivation ($\beta = 0.274$), information ($\beta = 0.192$), maternal education ($\beta = 0.158$), behavioral skills ($\beta = 0.155$), and personal motivation ($\beta = 0.139$) (Fig. 1B).

However, regression diagnostic plots identified potentially influential observations with a high studentized residual (Fig. 2). Following its exclusion, the standardized coefficient for social motivation increased from 0.213 to 0.274, indicating a stronger association with OHL in the sensitivity analysis. Personal motivation also became a significant predictor, suggesting that the influential observation affected its estimated association with OHL. In contrast, the standardized coefficient for maternal education decreased from 0.212 to 0.158, indicating that its estimated effect was reduced after removal of the influential observation.

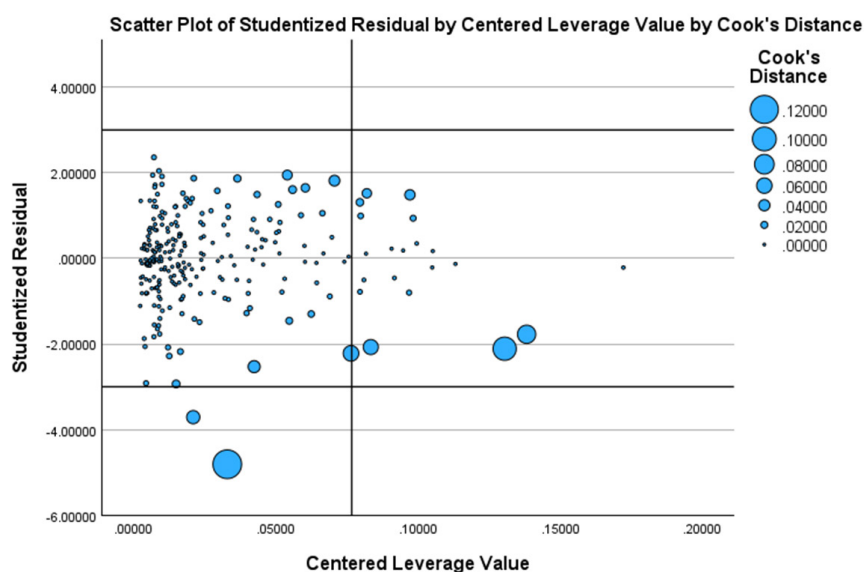


Figure 2 Scatter plots of leverage (hat values) versus studentized residuals for influence diagnostics in the regression models: Horizontal reference lines indicate studentized residuals of ± 3 , and the vertical line indicates the leverage cutoff ($3p/n$). These plots were used to assess potentially influential observations: high studentized residuals values

Discussion

Health literacy is defined as the knowledge and competencies that enable individuals to access, understand, appraise, and use health information and services to promote and maintain their own health and well-being, as well as that of those around them.²³ The present study extended this concept by incorporating the Information–Motivation–Behavioral Skills (IMB) model to identify determinants of oral health literacy (OHL) among school children. The IMB model conceptualizes the psychological determinants of health behaviors through three key constructs: Information and knowledge about the behavior; the motivation of an individual to perform the behavior; and

the behavioral skills necessary to perform the behavior.²⁴ To the extent that individuals are well informed, motivated to act, and possess the requisite behavioral skills for effective action, they will be likely to initiate and maintain health-promoting behaviors and experience positive health outcomes. In contrast, to the extent that individuals are poorly informed, unmotivated to act, and lack the behavioral skills required for effective action, they will tend to engage in health-risk behaviors and experience negative health outcomes.²⁵

Consistent with the IMB framework, the present study found that information, social motivation, and

behavioral skills were independently associated with higher OHL after adjustment for maternal education, personal motivation, oral hygiene status, and dental caries experience. The standardized regression coefficients were relatively similar in magnitude, indicating that these factors contributed comparably to OHL. Among them, social motivation showed the largest standardized regression coefficient, although its effect size was only slightly greater than those of maternal education, information, and behavioral skills. These findings support the IMB model, suggesting that adequate knowledge, supportive social influences, and practical behavioral skills are all important contributors to the oral health behavior of children. The significant association between social motivation and OHL highlights the potential influence of family members, peers, teachers, and other social environments on the acquisition and application of oral health information by children. These findings are consistent with prior research emphasizing the importance of parental involvement and social reinforcement in shaping the health behaviors of children. Parents and caregivers play a central role in shaping the oral health behaviors of children. Accordingly, they should be educated on dental caries prevention.²⁶ Strengthening social support within families and schools may therefore enhance oral health literacy of children and reinforce healthy oral health practices. Maternal education remained an independent predictor of OHL after adjustment for other variables, underscoring the significance of family educational background in the oral health literacy of children. Although maternal oral health literacy was not directly measured in the present study, previous research has shown that lower maternal OHL is associated with poorer oral health behaviors among children.²⁷ Other studies have likewise reported improving mothers' OHL might help strengthen their capacities to promote oral health, thus helping to improve their children's dental health and reduce inequalities.²⁸ This underscores the significance of educational initiatives designed to enhance the mothers' understanding of oral health, ultimately contributing to better dental health outcomes for their children.²⁹ Behavioral skills were also independently

associated with OHL, suggesting that children who possess greater confidence and practical skills for performing oral health behaviors are more likely to understand and apply oral health information effectively. This finding is consistent with the IMB model, which proposes that behavioral skills facilitate the translation of knowledge and motivation into health-related behaviors.^{24,25} Information likewise remained a significant predictor of OHL, supporting the concept that adequate oral health knowledge provides an important foundation for the ability of children to access, understand, and apply oral health information.

The sensitivity analysis further strengthened the interpretation of the findings. After excluding influential observations identified through regression diagnostics, the overall model fit improved and personal motivation became a significant predictor of OHL. Although the overall pattern of significant predictors remained consistent, this finding suggests that the association between personal motivation and OHL was influenced by the presence of the influential observation. Because the excluded observation represented a valid data point rather than a data error, both models were retained and interpreted. Nevertheless, the sensitivity analysis produced a model in which all IMB constructs were significantly associated with OHL, providing findings that more closely align with the theoretical IMB framework. These results also demonstrate the importance of conducting regression diagnostics and sensitivity analyses to evaluate the robustness of multivariable models. In contrast, neither oral hygiene status (DI-S) nor dental caries experience (DMFT or dmft) was significantly associated with OHL. Although both DMFT and dmft were included to capture cumulative caries experience during the mixed dentition stage, these findings suggest that higher OHL alone may not necessarily translate into better clinical oral health outcomes. The inclusion of both DMFT and dmft nevertheless provided a more comprehensive assessment of cumulative caries experience during the mixed dentition period, when retained primary teeth remain susceptible to dental caries. Collectively, these findings have important implications for oral health promotion. Interventions designed to improve the OHL of children should address multiple

IMB components by strengthening oral health knowledge, enhancing social motivation through parental and school support, developing practical behavioral skills, and fostering personal motivation. Previous studies have demonstrated that IMB-based interventions effectively promote behavior change, improve self-management, treatment adherence, and quality of life across various health conditions.^{30,31} IMB-based interventions have also been shown to enhance preventive behaviors and self-efficacy, including in oral health settings.^{32,33} The present findings therefore support the application of the IMB framework in designing theory-driven, digitally delivered oral health interventions for schoolchildren.

This study has several strengths. First, it is grounded in the Information–Motivation–Behavioral Skills model, providing a strong theoretical framework for understanding determinants of the oral health literacy of children. Second, the integration of psychosocial constructs, maternal education, and clinical oral health indicators enabled a comprehensive assessment of factors associated with OHL. Third, advanced regression diagnostics, including the identification of influential observations and sensitivity analysis, enhanced the robustness and transparency of the statistical analyses. Finally, the findings provide evidence that can inform the development of targeted interventions to improve oral health literacy among schoolchildren.

Several limitations should also be acknowledged. First, the regression results were sensitive to one influential observation, which affected model fit and the statistical significance of personal motivation, indicating that some associations should be interpreted cautiously. Second, the cross-sectional design precludes causal inference regarding the relationships between IMB constructs and OHL. Third, the use of self-reported measures may have introduced recall and social desirability bias. Fourth, although maternal education was included in the analysis, other potentially important socioeconomic and environmental factors, such as household income, parental oral health practices, and access to dental care, were not measured and may have influenced the observed associations. Finally, although both DMFT and

dmft were included to account for the mixed dentition stage, the dmft index reflects caries experience in retained primary teeth and may not fully represent the current oral health status of the children. In addition, the use of convenience sampling and school selection based on administrative approval and accessibility may limit the generalizability of the findings. Future studies should therefore include larger, randomly selected, and geographically diverse populations to improve external validity.

Future research should employ longitudinal study designs to clarify the temporal relationships between IMB constructs and OHL and evaluate the long-term effectiveness of IMB-based interventions. Studies should also investigate the integration of school-based, family-centered, and community-level approaches to address broader determinants of the oral health of children. Furthermore, the development and evaluation of culturally tailored digital interventions may provide an effective strategy for improving oral health literacy and promoting positive oral health behaviors among children, particularly in resource-constrained settings.

Conclusion

Oral health literacy in Filipino schoolchildren is influenced by both individual behavioral factors and the family environment. Children with better oral health information, stronger motivation, greater behavioral skills, and mothers with higher educational attainment tended to have higher oral health literacy, underscoring the interconnected roles of knowledge, psychosocial factors, and parental influences. These findings support the Information–Motivation–Behavioral Skills (IMB) model as a valuable framework for understanding and promoting oral health literacy in children.

Improving oral health literacy requires more than providing information alone. Oral health promotion programs should also strengthen motivation of children, self-efficacy, and supportive social environments while actively engaging parents and caregivers. School-based and family-centered approaches, particularly those incorporating digital health education, may help improve oral health literacy and contribute to reducing oral health

inequalities among children. Future longitudinal and intervention studies are needed to confirm these findings and evaluate the long-term effectiveness of IMB-based oral health promotion strategies.

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Conflict of Interest

The authors declare no potential conflicts of interest related to this research, authorship, or publication.

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Establishing a Reference Limit for Normal Alveolar Bone Level Using Bitewing Radiographs in a Sample of Young Thai Dental Students

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Abstract

The normal limit of 2 mm distance between cemento-enamel junction (CEJ) and alveolar crest (AC) has been generally accepted for decades. However, the medical reference interval of this parameter has not been investigated. This study aimed to establish reference intervals for normal alveolar bone levels and to identify factors influencing these levels in a Thai population. Digital bitewing radiographs were obtained from 100 dental students without interdental attachment loss. Alveolar bone level was assessed by measuring the distance between CEJ and AC. The right-sided 95% reference limit for the CEJ-AC distance was calculated. Multilevel modeling was used to identify tooth-level and subject-level factors associated with CEJ-AC distance. The mean ($\pm$ SD) CEJ-AC distance was 1.00 ± 0.41 mm, with a 95% upper reference limit of 1.73 mm (90% confidence interval: 1.71, 1.77). Mandibular molars had the smallest mean CEJ-AC distance (0.86 mm) compared to other tooth types (1.03-1.09 mm). Correspondingly, the 95% upper reference limit for mandibular molars was 1.49 mm, while values for other tooth types ranged from 1.68 to 1.77 mm. Tooth type was significantly associated with CEJ-AC distance ($p < 0.001$), while age, sex, and previous orthodontic treatment were not ($p > 0.05$). The 95% upper reference limit for CEJ-AC distance in this population was lower than the widely accepted 2-mm threshold and varied significantly by tooth type.

Keywords: Alveolar bone loss, Periodontal Attachment Loss, Periodontal Index, Radiography, Reference Standards

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Introduction

Alveolar bone loss is commonly assessed alongside clinical attachment loss (CAL) for the early detection and diagnosis of periodontitis.^{1,2} In patients without CAL, the distance between cemento-enamel junction (CEJ) and

alveolar bone crest (AC) approximates the supracrestal tissue attachment where connective tissue attachment is present. The CEJ-AC distance can be evaluated using radiographs, such as a paralleling bitewing projection.

A CEJ-AC distance that exceeds a defined threshold of biologic width is typically interpreted as indicative of bone loss and subsequently attachment loss. A landmark study of 18-year-old Swedish adolescents found that the maximum CEJ-AC distance observed in clinically healthy sites was 2 mm.³ A study on British adolescents yielded a similar upper bound, with a 95% confidence interval (CI) for CEJ-AC distance ranging from 0.4 to 1.9 mm at tooth sites without CAL.⁴ Based on these studies, a CEJ-AC distance of 2 mm has been widely accepted as the radiographic threshold for bone loss.^{5,6} A more recent study in post-menopausal women also showed CEJ-AC distance within the 2-mm threshold in periodontally healthy participants.⁷

In medical diagnostics, reference intervals serve as a decision-making tool for distinguishing normal biological variation from pathological findings.⁸ A reference interval is defined as the range within which a specified percentage (typically 95%) of values from a healthy population are expected to fall. Despite their clinical importance, no studies to date have formally established reference intervals for CEJ-AC distance using standardized methods, such as those recommended by the Clinical and Laboratory Standards Institute (CLSI).⁹ While the 95% CI reported by Hausmann *et al.* (1991) provides useful information, it is conceptually and statistically distinct from a reference interval: CIs reflect the precision of a sample estimate, whereas reference intervals define the expected range of values in a healthy population.¹⁰ Moreover, most existing studies on CEJ-AC distance have been conducted in Western populations, limiting their generalizability to other ethnic groups.^{3,4} Traditional thresholds also rarely account for variation across different tooth types, and the influence of subject-level factors—such as age, sex, and history of orthodontic treatment—has not been thoroughly explored.

The present study aimed to address these gaps by determining CEJ-AC distances from bitewing radiographs in a young Thai population without interdental CAL. Reference intervals were established at both the population- and tooth-specific levels in accordance with CLSI guidelines. Additionally, factors potentially influencing CEJ-AC distance—including tooth type, age, sex, and orthodontic history—were examined using a multilevel modeling approach.

Materials and methods

Study participants

The calculated sample size was 102 participants, using G*Power software (version 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Germany) with 0.05 alpha and 0.8 power based on data from Wong *et al.*¹¹ This study involved 133 volunteer undergraduate students from the first to the fifth years at the Faculty of Dentistry, Chulalongkorn University, all of whom were non-smokers and of Thai ethnicity (Fig. 1). Participants with interdental CAL or those undergoing orthodontic treatment at the time of the study were excluded. Demographic information and orthodontic treatment history were collected through a questionnaire. Ethical approval was granted by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2023-057). All participants provided written informed consent.

The final study samples were 100 dental students, 19-25 years old (mean $\pm$ SD = 21.77 $\pm$ 1.36). Seventy percent were females, and 59% had a history of orthodontic treatment. Despite a reduced number of participants (only 100 participants present compared to the calculated 102 participants), the effects from the loss of samples were assumed to be minimal and the final number of participants was considered to remain sufficient. Of the 3,016 tooth sites available for radiographic examinations, 2,155 sites were included for analysis (Fig. 2).

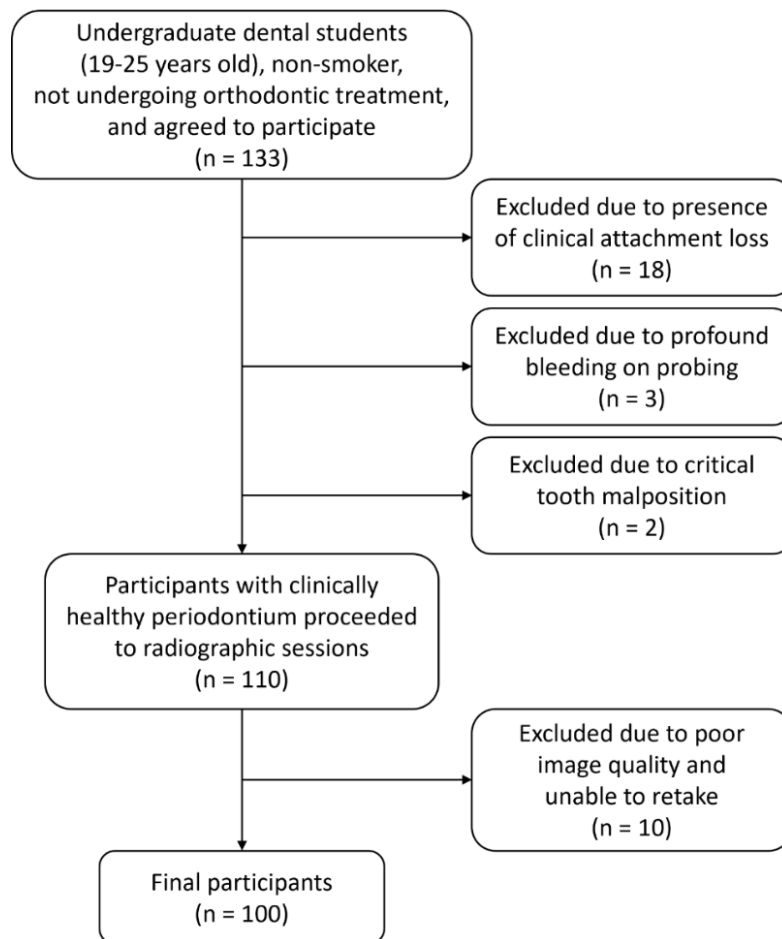


Figure 1 Flow diagram of the participants included in the present study

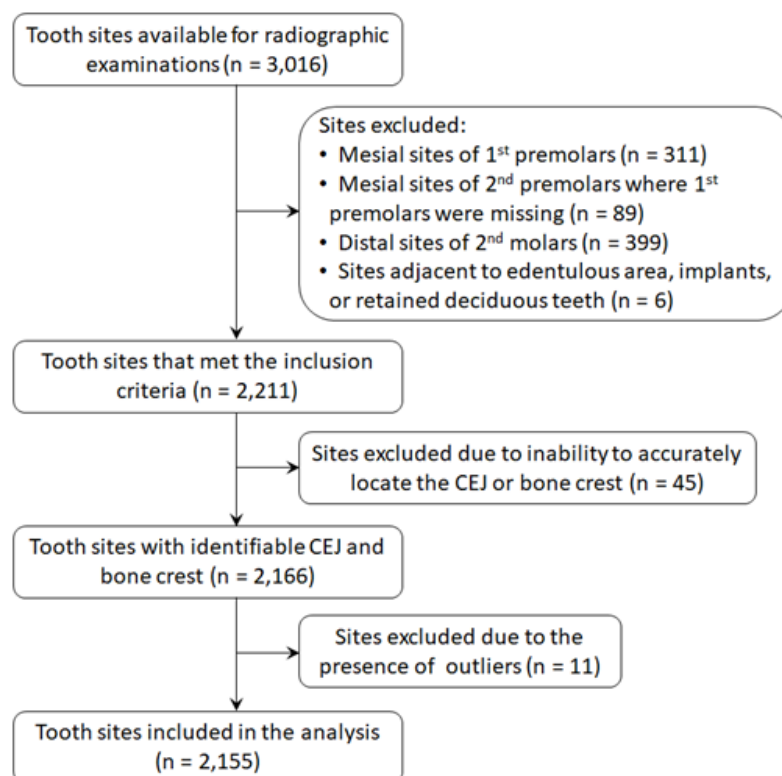


Figure 2 Flow diagram of the tooth sites included in the present study

Bitewing radiographs

A series of 4–6 digital bitewing radiographs were obtained for each participant, covering four posterior teeth—from the first premolar to the second molar—in each quadrant. Radiographs were positioned using a bitewing receptor-holding instrument (Rinn XCP; Dentsply Sirona, Charlotte, NC, USA). The images were captured with No. 2 photostimulable phosphor plates (KaVo ProXam iP; Kavo, Tuusula, Finland) using intraoral x-ray machines (Planmeca ProX; Planmeca, Helsinki, Finland) with exposure settings of 60 kV, 7 mA, and 0.25 seconds. Professional radiographers from the Department of Radiology, Chulalongkorn University, conducted all imaging procedures. The image quality was controlled as (1) adjacent teeth were not overlapped or less than half of enamel thickness overlapped; (2) absence of elongation or foreshortening; (3) supposed alveolar crest was visible on the images and both maxillary and mandibular teeth were proportionately visible; (4) enamel, dentin and pulp were optimally distinct with neither burnout nor underexposure; and (5) absence of blurring and other imaging artifacts.

The images were transferred to the hospital Picture Archiving and Communication System (Infinit; Infinit Healthcare, Seoul, South Korea) for analysis. Radiographs were viewed on a dedicated diagnostic monitor (Coronis Fusion 6MP; Barco, Kortrijk, Belgium) under normal room lighting. Magnification, contrast, and brightness were adjusted individually by each examiner to ensure visibility of the whole tooth outline. Relatively low contrast and increased brightness were applied to reveal the cervical region, including the margins of CEJ, AC and tooth proximal surface.

Radiographic measurements

Two undergraduate students independently examined the radiographs, unaware of participant information including the clinical condition. The CEJ-AC distance was measured from the first premolar to the second molar. The distal aspect of the second molars was excluded due to potential bone loss from impacted or extracted third molars, and the mesial aspect of the first premolars was excluded due to non-orthogonal

radiographic projections. Additionally, the mesial aspect of the second premolars was excluded when the first premolars were missing, as were tooth sites adjacent to edentulous areas, implants, or retained deciduous teeth.

Measurements were taken as the straight-line distance from the CEJ to the AC at each proximal site (Fig. 3). The CEJ and AC were identified based on the recommendations by Hausmann and colleagues.⁴ If the same tooth site appeared in multiple images, the selection was based on the following criteria: (1) the most clearly identifiable CEJ and AC, (2) minimal overlap of proximal contacts, and (3) maximum overlap of buccal and lingual cusps. Tooth sites where the CEJ or AC could not be accurately identified due to restorations, tooth malposition, or poor image quality were excluded from the analysis.

Measurement landmarks were described in detail as:

(1) Cemento-enamel junction is the junction where there are both clear changes in density and in contour between crown enamel and root surface.

a. In cases where the changes in density and contour were not in the same location, the density change was considered.

b. If either density or contour was poorly-defined, CEJ was considered by the other well-defined aspect.

c. When both density and contour changes could not be defined, the site was excluded.

d. In cases of maxillary molars, if separated buccal and palatal CEJs were observed on the same tooth side, the buccal CEJ was selected.

(2) An alveolar crest is an interproximal alveolar bone which is the most coronal and closest to the root surface, and where there is a definite change in density.

a. In sites where the alveolar outline diverted from the root surface, the starting point of diversion was considered.

b. In cases where two alveolar crests were present at the same site, effects from minor vertical projection were assumed.

i. If a vertical discrepancy between the buccal and lingual cusp tips was observed, the most apical alveolar crest would be the reference point.

ii. If the buccal and lingual tooth cusps overlapped properly, the most coronal alveolar crest would be the reference point.

c. In areas where the alveolar crest is located coronal to the CEJ, the site was excluded since an inappropriate projection angle could be assumed.

(3) Periodontal ligament (PDL) region was defined as PDL space width narrower than 0.5 mm (Fig. 3).

a. In cases of constant PDL space width under 0.5 mm, the coronal end of the alveolar crest was considered for measurement.

b. In cases of slope alveolar crests with varying PDL space width, the landmark for alveolar crest was the coronal end of PDL region where PDL space width was less than 0.5 mm.

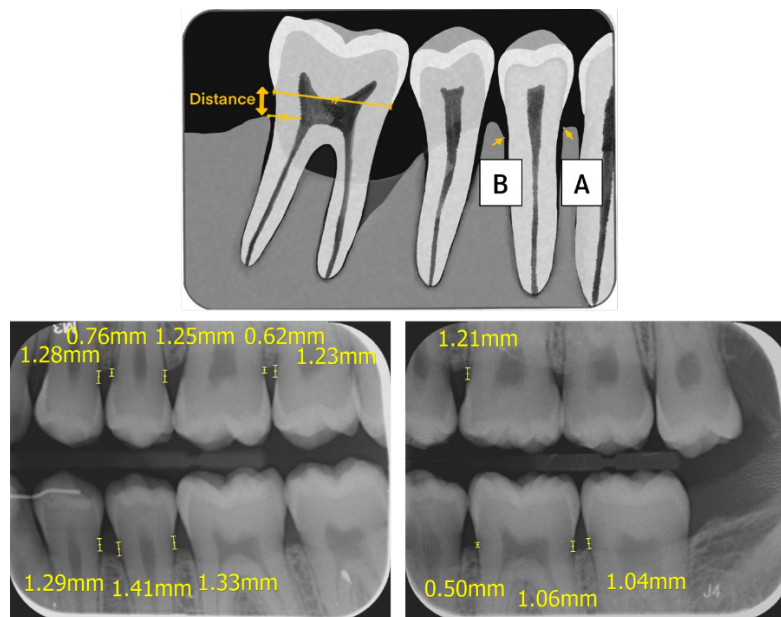


Figure 3 Diagram and radiographs showing CEJ-AC distance measurement. The double arrow presents the distance between the CEJ and AC. The landmarks for alveolar crest in cases of PDL space constantly < 0.5 mm (A) and varying PDL space width (B) are shown.

Inter- and intra-examiner reliability

The examiners (PT and NK) received training and calibration from a radiologist with eight years of experience in the field before the study. During the calibration process, bitewing radiographs from ten random patients (4-6 images per patient), not included in the study samples, were viewed by the main examiners and the radiologist. All three examiners discussed an exact location for measuring CEJ-AC distance until a consensus was achieved. Later, the inter-rater and intra-rater reliability were evaluated using the intraclass correlation coefficient (ICC) based on 295 measurements from 40 radiographs across ten participants from the present study, and interpreted following the suggestion by Koo and Li (2016).¹² For the intra-rater reliability test, the second measurement was performed one month after the first examination. The ICC for agreement between

the examiner and the radiologist was 0.875 (good) (95% CI: 0.839, 0.904). The intra-rater reliability for each examiner was 0.966 (excellent) (95% CI: 0.950, 0.976) and 0.903 (excellent) (95% CI: 0.873, 0.926), respectively. Furthermore, the inter-rater reliability between the two examiners was 0.883 (good) (95% CI: 0.850, 0.909).

Reference interval calculations

The 95% reference interval for the normal CEJ-AC distance was calculated using MedCalc v23.0.5 (MedCalc Software Ltd., Ostend, Belgium) in accordance with the CLSI guidelines C28-A3.⁹ Box plots were used for data inspection, and outliers were identified and excluded using the Tukey method to ensure that the analyzed data represented the non-diseased population. Since the lower reference limit for the CEJ-AC distance did not have diagnostic relevance, a one-sided upper reference

interval was calculated. The D'Agostino-Pearson test was applied to assess data normality. For normally distributed data, the upper reference limit was determined using the normal distribution method. For non-normally distributed data, the upper reference limit (95th percentile) was determined using the non-parametric percentile method. Additionally, 90% CI for the upper reference limit was calculated.

Statistical analysis

Analyses were performed using IBM SPSS Statistics v29.0 (IBM, Chicago, IL). Statistical significance was defined as $p < 0.05$. ICC estimates and their 95% CI were calculated using a single-rating, absolute-agreement, two-way mixed-effects model.

Given the hierarchical structure of the data, which included both tooth- and participant-level variables, multilevel analyses were conducted using a linear mixed model to examine factors influencing the CEJ-AC distance. An initial model, fitted without predictors, revealed that 24.5% of the variance in CEJ-AC distance was attributable to between-subject variations ($p < 0.001$), justifying the use of a multilevel modeling approach. Consequently, models were fitted to evaluate the effect of tooth-level factors (tooth type) and participant-level factors (age, sex, and previous orthodontic treatment) on CEJ-AC

distance. Due to the limited age range included in the study, the participants were categorized into younger (19-21.9 years) and older (22-25 years) age groups to identify possible effects from age.

Results

The CEJ-AC distance

The distribution of overall CEJ-AC distance was non-normal, as the distance differed between tooth types; therefore, the reference limit from all tooth sites was analyzed by the non-parametric percentile method. The overall mean CEJ-AC distance ($\pm$ SD) was 1.00 ± 0.41 mm, with a 95% upper reference limit of 1.73 mm (90% CI: 1.71, 1.77) (Table 1). In contrast, normal distribution was found in cases of separated tooth types, in which the normal distribution method was applied. The mandibular first and second molars exhibited the smallest mean CEJ-AC distances (0.85-0.86 mm), whereas the distal aspect of the mandibular second premolars showed the largest mean distances (1.14 mm). The 95% upper reference limits were also lowest at the mandibular first and second molars (1.47-1.50 mm). However, the highest upper limit was observed at the distal aspect of the mandibular first premolars (1.83 mm).

Table 1 Mean and 95% upper reference limits for the CEJ-AC distance (mm) by tooth site.

Tooth	Site	N (sites)	Mean $\pm$ SD	95% upper reference limit (90% CI)*
Maxillary				
1 st premolar	D	141	1.05 $\pm$ 0.40	1.71 (1.61, 1.80)
2 nd premolar	M	141	1.00 $\pm$ 0.37	1.60 (1.51, 1.69)
	D	196	1.11 $\pm$ 0.36	1.71 (1.63, 1.78)
1 st molar	M	195	1.10 $\pm$ 0.40	1.77 (1.69, 1.85)
	D	192	0.95 $\pm$ 0.41	1.62 (1.54, 1.71)
2 nd molar	M	187	1.02 $\pm$ 0.45	1.77 (1.68, 1.86)
Mandibular				
1 st premolar	D	159	1.10 $\pm$ 0.45	1.83 (1.73, 1.94)
2 nd premolar	M	162	1.03 $\pm$ 0.43	1.74 (1.64, 1.84)
	D	195	1.14 $\pm$ 0.36	1.74 (1.66, 1.81)
1 st molar	M	195	0.85 $\pm$ 0.38	1.47 (1.39, 1.55)
	D	196	0.86 $\pm$ 0.39	1.49 (1.41, 1.57)
2 nd molar	M	196	0.86 $\pm$ 0.39	1.50 (1.42, 1.58)
Total		2155	1.00 $\pm$ 0.41	1.73 (1.71, 1.77)

Abbreviations: AC, alveolar crest; CEJ, cemento-enamel junction; CI, confidence interval; D, distal; M, mesial.

*The upper reference limit for all tooth sites was determined using the non-parametric percentile method due to the non-normal distribution of the data, whereas values for individual tooth sites were determined using the normal distribution method.

To facilitate analysis, tooth types were grouped into four categories: maxillary premolars, maxillary molars, mandibular premolars, and mandibular molars (Table 2). Among these, mandibular molars had the lowest mean CEJ-AC distance (0.86 mm), compared to

other tooth types (1.03-1.09 mm). Correspondingly, the 95% upper reference limit for mandibular molars was 1.49 mm, while the upper limits for other tooth types ranged from 1.68 to 1.77 mm.

Table 2 Mean and 95% upper reference limits for the CEJ-AC distance (mm) by tooth type.

Tooth	Mean ± SD	95% upper reference limit (90% CI)*
Maxillary premolar	1.06 ± 0.38	1.68 (1.63, 1.73)
Maxillary molar	1.03 ± 0.43	1.73 (1.68, 1.78)
Mandibular premolar	1.09 ± 0.41	1.77 (1.72, 1.83)
Mandibular molar	0.86 ± 0.38	1.49 (1.44, 1.53)

Abbreviations: AC, alveolar crest; CEJ, cemento-enamel junction; CI, confidence interval; D, distal; M, mesial.

*The upper reference limit for each tooth type was determined using the normal distribution method

Factors influencing CEJ-AC distance

After adjusting for subject-level factors, tooth type was significantly associated with CEJ-AC distance ($p < 0.001$) (Table 3). Maxillary premolars, maxillary molars, and mandibular premolars had significantly larger CEJ-AC distances compared to mandibular molars, with regression coefficients ($\pm$ standard errors) of 0.211 ± 0.028 , 0.176

± 0.027 , and 0.238 ± 0.028 , respectively. In contrast, no significant associations were observed between subject-level factors—including age ($p = 0.114$), sex ($p = 0.089$), or prior orthodontic treatment ($p = 0.688$)—and CEJ-AC distance. Furthermore, no significant interactions were detected among subject-level factors or between tooth-level and subject-level factors ($p > 0.05$).

Table 3 Multilevel analysis of the association between tooth-level and subject-level factors and the CEJ-AC distance.

Variables	$\beta \pm se$	95% CI	p value
Tooth type			
Upper premolars	0.211 ± 0.028	0.155, 0.267	< 0.001
Upper molars	0.176 ± 0.027	0.122, 0.230	< 0.001
Lower premolars	0.238 ± 0.028	0.183, 0.293	< 0.001
Lower molars	0	-	-
Age (22-25 vs 19-21.9 yr)	0.068 ± 0.042	-0.016, 0.152	0.114
Sex (female vs male)	-0.081 ± 0.047	-0.173, 0.012	0.089
Past orthodontic treatment (yes vs no)	-0.018 ± 0.044	-0.105, 0.069	0.688

Abbreviations: AC, alveolar crest; β , regression coefficient; CEJ, cemento-enamel junction; CI, confidence interval; se, standard error.

For random effect: residual variance = 0.103 (se = 0.003, $p < 0.001$); intercept variance = 0.034 (se = 0.006, $p < 0.001$); tooth type variance = 0.019 (se = 0.003, $p < 0.001$); adjusted ICC = 0.343, conditional ICC = 0.318.

Discussion

This study established population- and tooth-specific reference intervals for CEJ-AC distances in a young Thai population without interdental CAL. The 95% upper reference limits for CEJ-AC distances by tooth site ranged from 1.47 to 1.83 mm, while the overall upper reference limit was 1.73 mm (90% CI: 1.71, 1.77). Among

the potential influencing factors examined, tooth type was significantly associated with CEJ-AC distance, whereas age, sex, and previous orthodontic treatment showed no significant associations.

The overall 95% upper reference limit of 1.73 mm indicates that 95% of CEJ-AC distances in a disease-free

population fall below this value. The narrow 90% CI reflects the precision of this estimate. Notably, this threshold is lower than the widely accepted 2-mm cutoff derived from studies in Western populations.^{3,4} This discrepancy may be attributed to differences in threshold determination methods or to ethnic differences in CEJ-AC distances.^{11,13} Previous studies have shown that East Asian participants tend to have greater CEJ-AC distances (1.10 mm in Asian¹¹, 0.97 mm in Chinese¹³) than individuals from other ethnic groups, such as Europeans (0.83 mm)¹¹, Indians (0.66 mm)¹³, or Malays (0.82 mm)¹³ possibly due to population-specific variations in crown and root morphology.^{14,15} The controversy between the present study and previous studies may relate to population specific variations and differences in research methods—including selection criteria, measuring procedures and tooth types. The identification of CEJ and AC, inclusion and exclusion criteria, and image quality assessment may be different between the studies. However, limited information was provided in the literature.^{11,13}

Measuring methods may also contribute to different outcomes. The earlier studies are based on conventional films, in which the image scale and resolution of measurement were limited.^{3,4,11} Some studies intended to scan conventional films and digitalize to improve performance; however, the ability to adjust the image remained restricted.^{4,11} The present study utilized the advantages of digital radiographs, which enable further image adjustment. Each observer was allowed to adjust the brightness and contrast of the images to suit personal visual perception. Magnification was applied to identify finer detail and precisely locate measurements. Although different magnification scales can contribute to variation in CEJ-AC distances, the errors were deemed minimal—supported by the results from reliability analysis. This flexibility in image adjustment is intended to overcome the limited image quality inherent to conventional film radiography, and is unlikely to compromise measurement reliability, as supported by the reliability analysis above. A more recent study also applied direct digital radiographs for the measurement of CEJ-AC distance. However, the detail on image adjustment was not provided.¹³

The present study demonstrated that tooth type was a significant determinant of CEJ-AC distance. Mandibular molars exhibited the smallest mean CEJ-AC distances, with an upper reference limit of 1.49 mm (90% CI: 1.44, 1.53), compared to 1.68-1.77 mm for other tooth types. These results align with previous reports indicating tooth-specific variation in CEJ-AC distance.^{3,11,13} Consistent with our findings, studies in New Zealand (involving both Asian and non-Asian participants) and Sweden reported the lowest mean CEJ-AC distances at the mandibular molars.^{3,11} In contrast, a study in Malaysia, which included three Asian ethnic groups, found the smallest distances at the distal aspects of the maxillary and mandibular first molars.¹³ Despite the discrepancies, these findings underscore the importance of considering tooth-specific thresholds when interpreting radiographic bone levels.

Individual characteristics such as age, sex, and orthodontic history were proposed as contributing factors on variations in CEJ-AC distances; however, the findings from the present study showed no significant effects.¹⁶ Previous research has shown that proximal CEJ-AC distances increase slightly with age (approximately 0.017 mm per year) in periodontally healthy individuals.¹⁷ However, the narrow age range of our participants (19-25 years) limits the ability to assess age-related variation. Regarding sex, our findings align with a previous study that found no significant difference in CEJ-AC distance between males and females.¹¹ Similarly, our results support earlier studies reporting no or only modest effects of orthodontic treatment on alveolar bone levels in individuals without periodontitis.^{18,19}

This study is the first to establish reference intervals for CEJ-AC distance based on standardized guidelines recommended by the CLSI. The clinical implications of our findings are noteworthy. Applying a universal 2-mm threshold to define bone loss across all populations may lead to underdiagnosis, particularly in young adults or at certain tooth types, where normative values are considerably lower. Further studies in diverse populations are warranted to establish population- and tooth-specific reference intervals to improve diagnostic accuracy. Additionally, as AI-driven diagnostic tools continue to evolve, incorporating more accurate thresholds into

these systems could further improve the precision of radiographic interpretation.²⁰

Selection strategies for the reference sample are critical to establishing accurate reference intervals.⁸ In this study, the absence of interdental CAL was used as an inclusion criterion to ensure that the sample truly represented a non-diseased population.² Additionally, outliers suggestive of undiagnosed attachment loss were excluded so that the reference intervals more accurately reflect normative values. However, some limitations of this study should be acknowledged. First, the final sample size (100 participants) was slightly smaller than previously calculated (102 participants) and less than the number of reference individuals recommended by CLSI (120 participants).⁹ Data from multiple teeth were included to compensate for this limitation, while multilevel model analysis was applied to reduce the effect from data clustering. Although the reference limit can be analyzed from the pooled tooth sites, the method remained inconsistent with the independence assumption. Moreover, the findings are based on a sample of young Thai dental students, which may limit their generalizability to other age groups or ethnicities. Further studies on a larger population are recommended to confirm the outcome.

The second limitation was the use of bitewing radiographs, which are limited to posterior teeth; therefore, CEJ-AC measurements in anterior regions were not assessed. Third, although radiographic techniques were standardized, inherent limitations of two-dimensional imaging—such as angulation errors or superimposition of anatomical structures—may affect accuracy and may not represent three-dimensional alveolar bone morphology of the patient.¹ These inconsistencies must be taken into account when applying the reference limit to other examination modalities. Lastly, it is important to emphasize that the reference limit of CEJ-AC distance represents a statistical distribution rather than a diagnostic threshold. Values exceeding the reference limit should not be interpreted as definitive evidence of periodontitis. Such values can also be found, albeit infrequently, in individuals without the disease.⁸

Therefore, radiographic findings should be interpreted in conjunction with clinical investigations.

Conclusion

The 95% upper reference limit for normal alveolar bone level in this population was lower than the widely used 2-mm threshold, particularly at the mandibular molars. The present findings raised awareness in periodontal screening as CEJ-AC distance between 1.73 mm and 2 mm may warrant closer monitoring, where comprehensive oral hygiene management should be applied to prevent disease progression. It is also remarkable that this study is based on highly selective samples which cannot directly imply a general population diagnostic threshold. Future research should aim to expand these reference values across different age groups and ethnicities.

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All authors declared no conflict of interest.

Data availability statement

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

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