COHORT STUDY

How Effective are Inferior Alveolar Nerve Block and Supplemental Intraligamentary Injections in Pediatric Patients with Deep Carious Permanent Mandibular Molars?

Papimon Chompu-inwai, DDS, MS[1] • Thitida Sutharaphan, DDS, MS[2] • Areerat Nirunsittirat, DDS, MMEd, PhD[3] • Patchanee Chuveera, DDS, MIPH[4] • Thanida Srisuwan, DDS, MS, PhD[5] • Thanapat Sastraruji, PhD[6]

Abstract: ***Purpose:*** *The purpose of this study was to assess, within the deep carious permanent mandibular molars of pediatric patients: (1) preoperative pulpal anesthesia following an inferior alveolar nerve block (IANB); (2) preoperative pulpal anesthesia following a supplemental intraligamentary injection (SII); and (3) intraoperative pulpal anesthesia.* ***Methods:*** *Vital permanent mandibular molars with deep caries were first anesthetized with IANB. Preoperative pulpal anesthesia was assessed, and success was defined when the tooth had no response to the sensibility tests. In cases with failed preoperative pulpal anesthesia, an SII was administered and pulpal anesthesia was reassessed. A maximum of three SIIs was allowed. Intraoperatively, pulpal anesthesia was determined when the Wong-Baker FACES Pain Rating Scale reported by the patients was no more than four.* ***Results:*** *Sixty molars of patients aged 10.9±2.9 years old were included. The success of preoperative pulpal anesthesia following IANB was 26.7 percent. In cases with failed IANB, SIIs were administered. The overall cumulative success rate of preoperative pulpal anesthesia was 80 percent. Intraoperatively, the success of pulpal anesthesia was 72.9 percent.* ***Conclusions:*** *The success of pulpal anesthesia by inferior alveolar nerve block in young permanent teeth with deep caries was low. A supplemental intraligamentary injection can greatly enhance preoperative pulpal anesthesia; however, 27.1 percent of patients still experienced pain during treatment. (Pediatr Dent 2018;40(7):437-42) Received June 7, 2018 / Last Revision October 7, 2018 / Accepted October 7, 2018*

KEYWORDS: PULPAL ANESTHESIA, INFERIOR ALVEOLAR NERVE BLOCK, SUPPLEMENTAL INTRALIGAMENTARY INJECTION, PEDIATRIC PATIENTS

Soft tissue anesthesia does not always guarantee pulpal anesthesia,[1] and inadequate pulpal anesthesia can result in a painful, traumatic experience. This can lead to a negative attitude toward future dental treatment, especially in young patients.[2] Inferior alveolar nerve block (**IANB**) has been the most common technique used for anesthetizing mandibular teeth; however, evidence of its pulpal anesthetic success in deep carious permanent mandibular molars of pediatric patients is currently lacking. Most previous studies regarding pulpal anesthesia by IANB have been performed in teeth with irreversible pulpitis in adults older than 18 years, with success rates reported between 10 and 75 percent.[3,4] However, differences between young and mature permanent teeth may affect pulpal anesthetic success. Young permanent teeth seem to have a greater pulpal response to the inflammatory process than do mature teeth because of the former's larger dentinal tubules.[5] Moreover, the young pulp with greater innervation can be extremely sensitive, and only minor injury and inflammation can affect its responses.[6]

Researchers have previously reported attempts to increase pulpal anesthetic success by changing the local anesthetic agents,[7] increasing the volume of the solution,[8] using adjunct drugs,[9] and using supplemental injections.[10] The supplemental intraligamentary injection (**SII**) has been one of the most studied supplemental methods in adults after failure of IANB because of its several advantages. First, an SII has immediate to rapid onset,[11] which generally is within 30 seconds.[12,13] Second, an SII can effectively increase the success of pulpal anesthesia; success rates of 48 to 70 percent have been reported in adult teeth with irreversible pulpitis.[10,14] Moreover, an SII can be administered under rubber dam isolation, making it convenient, especially during pulp treatment.[15]

The purpose of this study was to assess, within the deep carious permanent mandibular molars of pediatric patients: (1) preoperative pulpal anesthesia following an inferior alveolar nerve block; (2) preoperative pulpal anesthesia following a supplemental intraligamentary injection; and (3) intraoperative pulpal anesthesia.

Methods

This study was approved by the Human Experimentation Committee of the Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand. The study details were explained to both pediatric patients and their legal guardians. If they agreed to participate, the patients and legal guardians signed assent and informed consent forms, respectively.

Sample size. The sample size calculation was based on a study by Kanaa et al.[10] in teeth diagnosed with irreversible pulpitis; they reported 32 to 84 percent success rates using pulpal anesthesia with different supplementary local anesthetic techniques after failure of IANB in healthy patients aged 18 years or older. With a 10 percent error limit and a significance level of 0.05, 52 to 96 teeth were required. Sixty teeth were included in this study.

Participants. The study recruited American Society of Anesthesiologists (ASA) 1 or 2 patients who attended the Pediatric Dentistry Clinic, Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand, between June 2014 and June 2015. The inclusion criteria included patients who: (1) were six to 18 years old; (2) had no hypersensitivities to articaine

[1]*Dr. Chompu-inwai is an assistant professor, Department of Orthodontics and Pediatric Dentistry,* [2]*Dr. Sutharaphan is a post-graduate student,* [3]*Dr. Nirunsittirat is an instructor and* [4]*Dr. Chuveera is an assistant professor, Department of Family and Community Dentistry,* [5]*Dr. Srisuwan is assistant professor, Department of Restorative Dentistry and Periodontology, and* [6]*Dr. Sastraruji is a researcher, Dental Research Center, all in the Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand.*

Correspond with Dr. Chompu-inwai at papimon.c@cmu.ac.th

or any components of the anesthetic agent; (3) did not take any analgesic drugs on the day of treatment; (4) were cooperative and able to communicate well (scoring three or four on the Frankl Behavior Rating Scale); (5) had a permanent mandibular molar with a deep carious lesion penetrating into three fourths or more of the entire dentin thickness, as presented on a posterior bitewing radiograph; and (6) had a tooth with a positive response to cold testing with Green Endo-Ice (Coltene Whaledent, Cuyahoga Falls, Ohio, USA). Each tooth was diagnosed with normal pulp or reversible or irreversible pulpitis, based on the clinical diagnosis criteria of the American Association of Endodontists.[16]

Study protocol. One postgraduate student in pediatric dentistry explained the scales used in this study to the participants in age-appropriate terms. The same dentist also performed all clinical procedures under supervision of one experienced instructor. The parent was present during the explanations and treatment.

Before treatment, the fear and anxiety level of each participant was measured using the Facial Image Scale (FIS).[17] The FIS consists of five figures of faces, ranging from a very happy to a very unhappy face. The children were asked to point at the face that matched their feelings.

Preoperative phase. The anesthetic agent used in all steps of this study was four percent articaine with epinephrine one in 100,000 (Septanest SP; Septodont, Saint-Maur-des-Fossés, France). The Figure shows the flow chart for this study. The carious tooth was anesthetized with IANB using a 27-gauge short needle (Terumo Dental Needle; Terumo Corporation, Tokyo, Japan). A three-quarter cartridge of anesthetic solution was initially deposited. After a 15-minute waiting period, lip and tongue anesthesia was confirmed. If there was no lip and tongue anesthesia, IANB could be readministered to a maximum of two injections. If there was soft tissue anesthesia, the tooth was further tested for preoperative pulpal anesthesia using both the Green Endo-Ice cold test and the electric pulp test (EPT; Kerr Vitality Scanner; SybronEndo, Glendora, Calif., USA). The success of preoperative pulpal anesthesia was defined as two consecutive negative responses to both tests.

In cases where preoperative pulpal anesthesia was achieved with IANB, a one-quarter cartridge of anesthetic solution was deposited using a long buccal nerve block to anesthetize the buccal soft tissue in order to facilitate the placement of a rubber dam clamp, and treatment was then initiated. However, if preoperative pulpal anesthesia failed to occur following an IANB, demonstrated by a positive response to pulp testing, SIIs were administered using 0.4 ml of anesthetic solution and 0.2 ml at the mesial and distal aspects via a pressure syringe (Ergoject Intralig Syringe; Anthogyr, Sallanches, France). Preoperative pulpal anesthesia was then retested. Up to three SIIs could be administered. After preoperative pulpal anesthesia was successful, a one-fourth cartridge of anesthetic solution was deposited using a long buccal nerve block to anesthetize the buccal soft tissue. Next, a rubber dam clamp was placed and treatment was begun. Teeth with preoperative pulpal anesthesia failure following three SIIs were excluded.

Intraoperative phase. During treatment, the success of pulpal anesthesia was determined using the Wong-Baker FACES Pain Rating Scale (WBFPS).[18] The WBFPS is a six-face picture scale with fixed scores from zero to 10, ranging from "does not hurt" to "hurts the worst." The patient was instructed to choose the face of the WBFPS that best described his or her feeling at that moment. The success of intraoperative pulpal anesthesia was determined when the WBFPS score was four or less. In failed cases, with the WBFPS score was six or greater, other supplemental injections, such as an

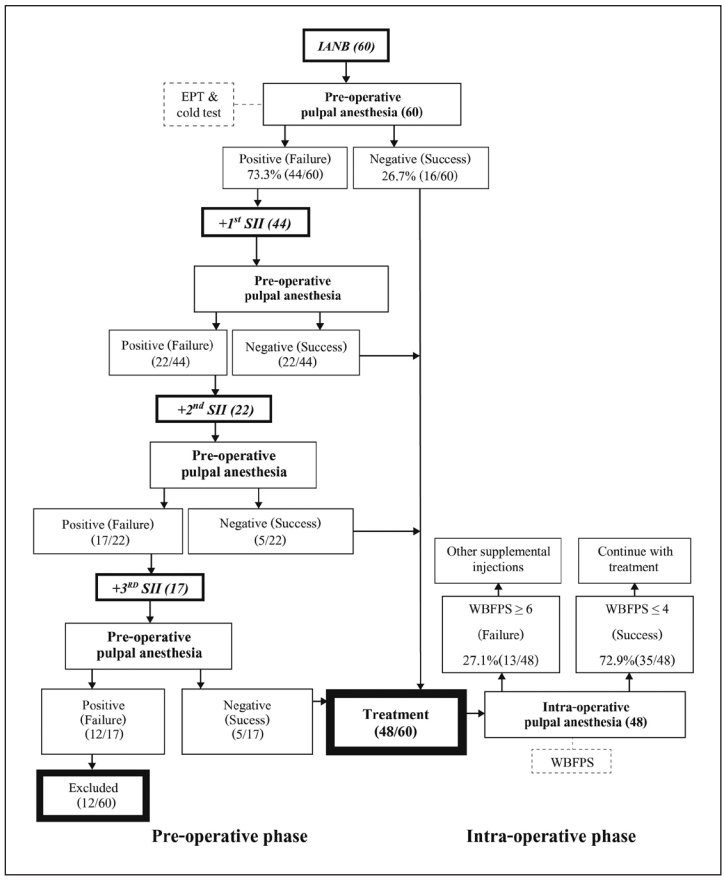

Figure. Flow chart of the study.

Table 1. BASELINE VARIABLES, INCLUDING AGE, GENDER, DIAGNOSIS, ANXIETY LEVEL, AND STAGE OF ROOT DEVELOPMENT

Baseline variables	
Age (years)	10.9±2.9
Gender: N (%)	
Male	27 (50.9)
Female	26 (49.1)
Total	**53 (100)**
Diagnosis: N (%)	
Normal pulp	29 (48.4)
Reversible pulpitis	17 (28.3)
Irreversible pulpitis	14 (23.3)
Total	**60 (100)**
Anxiety levels (FIS): N (%)*	
None to mild (1-3)	49 (84.5)
Moderate to severe (4-5)	9 (15.5)
Total	**58 (100)**
Stage of root development: N (%)	
G	22 (36.7)
H	38 (63.3)
Total	**60 (100)**

* Missing data: two cases. † FIS: Facial image scale.

intrapulpal injection, were added. However, the anesthetic solutions must not exceed the calculated maximum dosage (seven mg per kg but not in excess of 500 mg).[19]

Statistical methods. The success of pre- and intraoperative pulpal anesthesia was expressed as percentages. Because the success of preoperative pulpal anesthesia was obtained from multiple repeated measurements for additional injections, a logistic regression with a generalized estimating equations (GEE) model was used to evaluate the association of number of injections and diagnoses with the success of preoperative pulpal anesthesia. The number of injections was adjusted for confounding factors in multivariable analysis. Fisher's exact test was used to compare intraoperative pulpal anesthesia between different diagnoses, with a significance level of $P<.05$. The software used for statistical analysis was SPSS 17.0 (SPSS Inc., Chicago, Ill., USA).

Results

Baseline variables, including age, gender, diagnosis, anxiety level, and stage of root development, are shown in Table 1. Sixty deep carious permanent mandibular molars (58 permanent first molars and two permanent second molars) from 53 healthy patients (27 males and 26 females) between seven and 18 years old (mean equals 10.9±2.9 years old) were included in this study. Nearly half of the teeth (48.4 percent) were diagnosed with normal pulp, 28.3 percent with reversible pulpitis, and 23.3 percent with irreversible pulpitis. The majority (84.5 percent) of participants' anxiety levels were in the range of none to mild.

Preoperative phase. The success rate of soft tissue anesthesia by IANB was 93.3 percent (56 out of 60). IANB was readministered in four cases; all patients then reported lip and tongue anesthesia prior to pulpal anesthesia testing.

Table 2 shows the success rates of preoperative pulpal anesthesia for different pulpal diagnoses. The overall success rate of pulpal anesthesia following IANB was 26.7 percent (16 out of 60). The preoperative pulpal anesthetic success was 37.9 percent (11 out of 29) in teeth with normal pulp, 11.8 percent (two out of 17) in teeth with reversible pulpitis, and 21.4 percent (three out of 14) in teeth with irreversible pulpitis.

The first SII increased by the preoperative pulpal anesthetic success rates to 36.7 percent, 24.2 percent, 47.0 percent, and 50.0 percent for teeth with all diagnoses, normal pulp, reversible pulpitis, and irreversible pulpitis, respectively.

The second SII increased by the preoperative pulpal anesthetic success rates to 8.3 percent, 6.9 percent, and 17.6 percent for teeth with all diagnoses, normal pulp, and reversible pulpitis, respectively. The second SII did not increase success in teeth with irreversible pulpitis.

The third SII increased by the preoperative pulpal anesthetic success rates to 8.3 percent, 10.3 percent, and 11.8 percent for teeth with all diagnoses, normal pulp, and reversible pulpitis, respectively. The third SII did not increase success in teeth with irreversible pulpitis. The overall cumulative success rates of preoperative pulpal anesthesia was 80 percent, 79.3 percent, 88.2 percent, and 71.4 percent for teeth with all diagnoses, normal pulp, reversible pulpitis, and irreversible pulpitis, respectively.

The association between diagnoses and preoperative pulpal anesthesia is shown in Table 3. Preoperative pulpal anesthesia was less successful in teeth with reversible pulpitis or irreversible pulpitis, with unadjusted odds ratios (**OR**) of 0.87 (95 percent confidence interval [**CI**] equals 0.37 to 2.03) and 0.45 (95 percent CI equals 0.15 to 1.31), respectively, than in teeth with normal pulp. After adjusting for the number of injections, the adjusted ORs were 0.85 (95 percent CI equals 0.31 to 2.29) in teeth with reversible pulpitis and 0.38 (95 percent CI equals 0.11 to 1.38) in teeth with irreversible pulpitis. However, there were no differences in the success rate of preoperative pulpal anesthesia between teeth with reversible pulpitis or irreversible pulpitis and that of teeth with normal pulp ($P=0.74$ and $P=0.14$, respectively).

Intraoperative phase. Forty-eight teeth that had successful preoperative pulpal anesthesia were included in the intraoperative phase. Intraoperatively, the success rate of pulpal anesthesia was 72.9 percent for all diagnoses, and was 87 percent, 66.7 percent, and 50 percent in teeth with normal pulp, reversible pulpitis, and irreversible pulpitis, respectively. There was no significant difference in intraoperative pulpal anesthetic success between teeth with different diagnoses ($P=0.07$).

Discussion

To the best of our knowledge, this present study is the first to examine pulpal anesthesia in permanent teeth with deep caries in patients younger than 18 years. The results demonstrated a 26.7 percent rate for preoperative pulpal anesthesia following

Table 2. SUCCESS OF PREOPERATIVE PULPAL ANESTHESIA FOR DIFFERENT PULPAL DIAGNOSES*

Injection	All diagnoses N (%)†	Normal pulp N (%)†	Reversible pulpitis N (%)†	Irreversible pulpitis N (%)†
IANB	16 (26.7)	11 (37.9)	2 (11.8)	14 (21.4)
IANB+1 SII	22 (36.7)	7 (24.2)	8 (47.0)	14 (50.0)
IANB+2 SII	5 (8.3)	2 (6.9)	3 (17.6)	0 (0.0)
IANB+3 SII	5 (8.3)	3 (10.3)	2 (11.8)	0 (0.0)
Overall success‡	48 (80)	23 (79.3)	15 (88.2)	10 (71.4)
Total	**60 (100)**	**29 (100)**	**17 (100)**	**14 (100)**

* IANB=inferior alveolar nerve block; SII=successive supplemental intraligamentary injections (i.e., 1, 2, 3; see Methods section).

† The success of initial inferior alveolar nerve block and then additional success for each successive supplemental intraligamentary injection.

‡ Overall success represents the cumulative success of accomplishing anesthesia.

Table 3. ASSOCIATION OF DIAGNOSIS AND SUCCESS OF PREOPERATIVE PULPAL ANESTHESIA USING A GEE MODEL*

Diagnosis	Unadjusted OR			Adjusted OR†		
	OR	95% CI	*P*-value	OR	95% CI	*P*-value
Reference: normal pulp						
Reversible pulpitis	0.87	0.37-2.03	0.74	0.85	0.31-2.29	.74
Irreversible pulpitis	0.45	0.15-1.31	0.14	0.38	0.11-1.38	.14

* GEE=generalized estimation equations; OR=odds ratio; CI=confidence interval.

† Adjusted for number of injections.

IANB in deep carious teeth with all diagnoses, and no significant difference was found between different diagnoses. Zero et al.[20] stated that dental caries can induce pulpal inflammation before bacteria actually invade the pulp, and the inflammatory process in the pulp seems to be more prevalent in young teeth. The subjects in this study were children with a mean age of 10 years, with immature pulps. Compared to mature permanent teeth, young permanent teeth have larger dentinal tubules, thus allowing bacterial byproducts to diffuse through more easily.[21] Additionally, young pulp contains greater innervation with less fibrous tissue and calcification,[22-25] making it more sensitive to noxious stimuli. Previous studies regarding pulpal anesthesia by IANB focused mainly on teeth with irreversible pulpitis in adults older than 18 years and reported a wide range of success between 10 and 75 percent.[3,4] The differences in methodology prevent a direct comparison between different studies, and further investigations regarding the effect of age on pulpal anesthesia are highly recommended.

Another possible cause of low pulpal anesthetic success that should not be overlooked is the fear and anxiety level of patients. Klingberg et al.[26] reported that the prevalence of dental fear and anxiety in children and adolescents was five to 20 percent. Consequently, young patients may give either false positive or false negative responses to the sensibility test, thus resulting in inaccurate pulpal anesthesia being reported. However, most of our patients (84.5 percent) had mild or no anxiety, and all of them were required to be cooperative to be included in this study.

The last possible cause of low success rate of pulpal anesthesia by IANB in this study may be the slow onset of pulpal anesthesia in some patients. Tortamano et al.[27] reported that the mean onset of pulpal anesthesia by IANB using four percent articaine and one in 100,000 epinephrine was 7.4 minutes. In this study, the authors chose to wait 15 minutes before testing the pulpal anesthesia to cover the subjects with possible delayed onset. However, Mikesell et al.[28] reported that the success rate of pulpal anesthesia after 15 minutes of IANB administration was only 40 to 50 percent, and 11 to 12 percent of their subjects had slow onset of pulpal anesthesia. Thus, it is possible that some of our subjects may have had slow onset of pulpal anesthesia, for longer than 15 minutes, but were already determined to have experienced anesthetic failure.

Clinicians should always be aware of insufficient pulpal anesthesia by IANB. As a result, one must prepare for supplemental injections. An SII was chosen as a supplemental technique in this study because it has immediate to rapid onset, its successful pulpal anesthesia is frequent and usually profound, and it can be administered conveniently under rubber dam isolation.[11] The pressure intraligamentary syringe was used in this study for a labor-saving reason; however, some studies have found that the type of syringe did not affect the success rate of SIIs[29,30]; thus the technique does not necessarily require special equipment. Nonetheless, several disadvantages of SIIs include their relatively short duration (30 to 45 minutes) of pulpal anesthesia, risks of producing bacteremia and damage to the injection equipment, and risks of peri- and post-injection discomfort.[12,29,31] An SII in the primary dentition has been demonstrated to be associated with enamel hypoplasia in permanent teeth[32]; however, such effects have never been reported in humans.

In this study, the first SII greatly increased the success of pulpal anesthesia for all diagnoses. This increase is probably the result of different mechanism of actions between IANB and SII. IANB is a nerve block technique by which the anesthetic solution is administered far away from the target tooth, while an SII is a form of intraosseous injection by which the anesthetic solution is administered directly and close to the target tooth.[11] However, the success of preoperative pulpal anesthesia following the first SII was still insufficient. Consequently, additional SIIs were necessary to achieve preoperative pulpal anesthesia. When the number of SIIs increases, the volume of anesthetic solution also increases and may be a factor affecting the increased success of pulpal anesthesia. However, the anesthetic solutions must not exceed the calculated maximum dosage for each patient. Walton and Abbott[11] reported 63 percent and 71 percent success of pulpal anesthesia after the first and second SII. In addition, Zarei et al.[14] reported that pulpal anesthetic success was 70 percent and 100 percent following the first and second SII in teeth with irreversible pulpitis. In this study, the second and third SII increased the success in teeth with normal pulp and reversible pulpitis; however, neither of the injections increased success in teeth with irreversible pulpitis. The contradicting results between this study and other studies may result from the fact that an SII is a technique-sensitive procedure and the most critical factor to its success is to inject under strong back pressure,[11] which may not have been present in every administration. Moreover, the age groups and criteria for success varied between studies.

A positive pulp response to pulp testing with a cold refrigerant or an EPT indicates that the tooth is not completely pulpally anesthetized[1]; therefore, the authors attempted to confirm pulpal anesthesia by using both pulp testing before the beginning of treatment. However, the results of this study confirmed the results of other previous studies that the negative response to pulp test preoperatively cannot guarantee complete pulpal anesthesia intraoperatively.[7,33] Only 72.9 percent of the treated teeth in this study had pulpal anesthetic success during treatment. When classified by diagnosis, the success of pulpal anesthesia during treatment was 87 percent, 66.7 percent, and 50 percent in teeth with normal pulp, reversible pulpitis, and irreversible pulpitis, respectively.

Although the differences weren't significant, the success during treatment seemed to decrease with the degree of pulpal inflammation. The peripheral nerve endings of the pulp (A-δ fibers) can elicit a negative response to thermal or electrical stimulation, but the inner pulp areas, which are rich in C fiber nerve endings may not be stimulated, thus resulting in under-diagnosis of incomplete pulpal anesthesia.[34,35] Moreover, inflammation of the dental pulp, especially in deep pulpal tissue, could explain the lower success rates based on a lower local pH level, tetrodotoxin-resistant sodium channel overexpression, increased prostaglandins E2 levels, and increased vasodilation.[36,37] Future investigations should review tests that are more accurate and able to predict pulpal anesthetic failure. Moreover, improvement of methods for achieving pulpal anesthesia should also be further investigated.

Conclusions

Based on this study's results, the following conclusions can be made:

1. Clinicians should keep in mind that an inferior alveolar nerve block often produces insufficient pulpal anesthesia in young permanent mandibular molars with deep caries, regardless of their diagnoses.

2. A supplemental intraligamentary injection can greatly increase preoperative pulpal anesthesia; however, 27.1 percent of patients still experienced pain intraoperatively.
3. The use of a sensibility test to confirm pulpal anesthetic status of the inflamed pulpal tissue seems to be insufficient.

Acknowledgments

This study was supported by the Research Fund for Postgraduate Students of the Faculty of Dentistry, Chiang Mai, University, Chiang Mai, Thailand. The authors also wish to thank M. Kevin O'Carroll, BDS, MSD, Professor Emeritus of the School of Dentistry, University of Mississippi Medical Center, Jackson, Miss., USA, and faculty consultant with the Faculty of Dentistry, Chiang Mai University, Thailand, for his assistance in the preparation of the manuscript.

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