Review Article

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Anesthetic efficacies of buccal with palatal injection versus buccal with intra-septal injection in permanent maxillary first molars of pediatric patients

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The high success rate of dental treatment is dependent on the cooperation of pediatric patients during procedures. Dental treatment often causes pain, particularly in children. The factors in providing treatment to pediatric patients include the characteristics and location of the tooth, profoundness of the anesthesia including the type of local anesthetic, and cooperation of the patient. Previous studies have examined several techniques to successfully achieve profound pulpal anesthesia in maxillary permanent teeth. The dentist should select the injection technique to be used based on patient needs. In children, either buccal with palatal injections or buccal with intra-septal injections may be used to anesthetize the permanent maxillary first molar. Buccal with palatal injections are commonly used prior to routine maxillary dental procedures. Currently, there are only a few studies on the employment of buccal with intra-septal injections to anesthetize permanent maxillary first molars in pediatric patients. This review will focus on efficacy of buccal with palatal versus buccal with intra-septal pulpal anesthesia of the permanent maxillary first molars in pediatric patients and aim to determine which technique should be used during routine dental procedures.

Keywords: Intra-septal Injection; Maxillary Buccal Injection; Palatal Injection; Pediatric Patients; Permanent Maxillary First Molars.

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INTRODUCTION

Restorative treatments involving the pulpal tissue often invoke pain. Effective pain control is the most important aspect of pediatric dental practicce [1]. Local anesthesia is routinely used to provide effective pain control, but it causes pain and discomfort during administration, especially in children. Many local anesthetic injection techniques are available to provide adequate anesthesia to the teeth, soft tissues, and hard tissues in children.

To provide pulpal anesthesia in maxillary teeth, maxillary buccal injection (MBI) is a simple procedure that is usually entirely atraumatic [2-7]. However, additional injection techniques, such as palatal injection (PI), in combination with MBI for increased pulpal anesthesia in maxillary molars, are sometimes required [8]. Previous studies have shown different pulpal

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anesthetic success rates of MBI with PI. A study by Guglielmo et al. [4] used an electric pulp tester (EPT) on anesthetized maxillary first molars with uninflamed pulps and reported a 95% pulpal anesthetic efficacy of MBI with PI.

In maxillary first molars with irreversible pulpitis, a study by Aggarwal et al. [3] reported a 70% pulpal anesthetic efficacy when the MBI with PI technique is used during endodontic access preparation. The decreased efficacy of the MBI with PI technique may be due to inflamed teeth. Although PI is a useful technique, the palatal mucosa and bone are compact with an underlying periosteum and abundant nerve supply. Distress during PI is mainly the result of needle penetration in the nerve supply area and displacement of the mucoperiosteum with anesthetic solution deposition. A study by Abdellatif et al. [1] found that 50% of children between 6–7 years experienced moderate to severe pain during PI. This study revealed an inverse relationship between the anesthesia pain score and cooperative behavior in children [1,9,10]. Therefore, alternative techniques that can provide a painless experience during injection should be considered.

Intra-septal injection (IS) may be a possible alternative to PI. Many previous studies have reported pain-free to mild pain experience with IS in adult patients [11-13]. Several studies have reported a 90% pulpal anesthetic efficacy using the IS technique [8,11,13-16]. Although most previous studies have been conducted on mandibular teeth [13,16-20], there is limited information on maxillary teeth [15]. Young children usually have thinner cortical bones that are more porous than those in adults; thus, better diffusion of anesthetic solution through cancellous bone could be expected [21-23]. Based on these previous studies, IS may be an alternative technique that can decrease pain during injection while simultaneously providing sufficient anesthetic efficacy for maxillary permanent teeth. Therefore, the aim of this review was to analyze pulpal anesthetic efficacies from previous studies on MBI with PI versus MBI with IS in permanent maxillary first molars of pediatric patients.

MAXILLARY BUCCAL INJECTION

MBI is the most commonly used pulpal anesthetic technique for maxillary teeth [2-5,7]. As shown in Fig. 1, the anesthetic solution is administered via the porous thin cortical plate, enters through the cancellous bone, and spreads to the pulpal tissue, causing anesthesia to the pulp of the tooth, buccal periosteum, connective tissue, and mucous membrane [2]. MBI is performed using the conventional technique wherein the needle is inserted through taut tissues of the muco-buccal fold over the apex of the tooth [2,24]. A 27-gauge short needle is suitable for MBI. MBI uses approximately 0.6 ml of anesthetic solution slowly injected to the area with the needle withdrawn after injection.

The onset of pulpal anesthesia with MBI, according to Sreekumar and Bhargava [25], is approximately 30 s. Whereas Reader et al. [8] recoded the onset of pulpal anesthesia at 4.5 min with lidocaine deposited in the maxillary first molar area; however, the onset of pulpal anesthesia was reduced by approximately 3–4 min with articaine. The duration of pulpal anesthesia with MBI in maxillary molars is approximately 45–50 min with lidocaine administration [8]. In another study, the duration of pulpal anesthesia was similar between lidocaine and articaine [7].

Malamed [2] reported the duration of anesthesia to be approximately 60 min with lidocaine and 60–75 min with articaine. However, the duration of soft tissue anesthesia is 180–300 min for both lidocaine and articaine [2,8]. Therefore, the advantages of MBI include easy administration with high success rate and less trauma.

PALATAL INJECTION

PI, as shown in Fig. 2, is a conventional technique used in dentistry that requires manipulation of palatal soft and hard tissues [26-29]. It is indicated for palato-gingival pain control and for achieving acceptable hemostasis

Fig. 1. Buccal infiltration was performed at the lowest point of the vestibule.

Fig. 2. The pressure was applied on palatal tissue to reduce pain from palatal injection.

during surgical procedures. A 27-gauge short needle, with the bevel of the needle placed against the gingival tissue, is positioned 5–10 mm from the free gingival margin for PI [2]. The needle is inserted at a 45-degree angle with a small volume of anesthetic solution deposited to the area. The needle is advanced approximately 3–5 mm until it contacts bone gently, 0.2 to 0.3 ml of anesthetic solution is deposited for adequate palatal soft tissue anesthesia.

Rapid pulpal anesthetic onset occurring within 3–4 mins is observed when using PI technique [30,31]. Studies by Reader et al. and Meechan et al. found that the duration of anesthesia was not more than 60 min, similar to a greater palatine nerve block [8,32]. The major disadvantage of the PI technique is pain during injection, caused by separation of the muco-periosteum and the high tissue pressure from the rapid injection of anesthetic solution, rather than the needle penetrating the oral mucosa [2,33-35]. Although most patients experience pain due to injection, reduced pain can be achieved by the application topical anesthesia [36] prior to injection, pressure application at the site of needle insertion, and slow deposition of the anesthetic solution [2].

Factors affecting pain associated with palatal injection

PI is one of the most painful procedures during dental treatment [8]. The needle is inserted through the alveolar mucosa, directed to an approximation of the root apex, and the anesthetic solution is deposited at the target area. The discomfort during intraoral injections can be attributed to needle penetration and solution deposition [37] at the injection site. Wahl et al. [38] reported that PI caused significantly more pain than anterior or posterior MBI or inferior alveolar nerve block (IANB). As shown in Table 1, previous studies have shown PI pain ranging from mild to moderate in adolescent and adult patients [35,39-42]. Only one previous study has been conducted on pain experienced when using the PI technique in children [1].

Abdellatif [1] studied 6–7-year-old patients who had undergone PI. The results of that study reported moderate to severe pain gauged using the Wong–Baker FACES pain rating scale (WBS); 22.6% reported being hurt a little bit, 27.4% reported being hurt even more, 40.3% said it hurt a whole lot, and 9.7% said it hurt the worst. The child’s behavior was negatively correlated with anesthesia pain scores. Accordingly, this painful experience may progress to dental fear, which might lead to future uncooperative behavior.

INTRA-SEPTAL INJECTION

In 1967, IS (Fig. 3) was first introduced by Marthaler for use prior to dental restoration [11]. This technique is the injection of anesthetic solution into the interdental septum, which flows through the porous crestal alveolar

Table 1. Randomized controlled trials involving injection pain produced by palatal infiltration

Author	Year	Sample size	Age (mean) (years)	Teeth	Anesthetic solution	Volume (ml)	Assessment tool	Mean pain score (SD)	Pain level
Meechan, et al. [36]	2002	17	20-24	Max. teeth	2% Lidocaine plain 2% Lidocaine 1:80,000AD	0.2	100-mm VAS	48.18 (16.14) 50.88 (15.86)	moderate pain
Nusstein, et al. [42]	2004	40	19-36 (27)	Max. 1st, 2nd premolar	2% Lidocaine1:100,000AD	N/A	170-mm VAS	53 (32)	mild to moderate pain
Fan, et al. [35]	2009	71	17.5-67 (25.37)	Max. teeth	4% Articaine 1:100,000AD	0.4	100-mm VAS	37.70 (6.43)	mild to moderate pain
Kumaresan, et al. [39]	2015	150	15-50 (35.9)	Max. teeth	2% Lidocaine 1:80,000AD	0.3	11-unit NRS	3.03 (N/A)	mild to moderate pain
Gazal, et al. [41]	2017	90	16-70	Max. teeth	2% Mepivaine 1:100,000AD 4% Articaine 1:100,000AD	0.4	100-mm VAS	MH – 51 (17.48) AH – 46 (22.01) Total – 48.3 (20)	moderate pain
Abdellatif [1]	2011	75	6-7 (6.3)	Max. molar	2% Lidocaine1:100,000AD	0.3	WBFPS (score 0-5)	2 = 22.6% 3 = 27.4% 4 = 40.3% 5 = 9.7%	2 = hurt little bit 3 = hurt even more 4 = hurt whole lot 5 = hurt worst

AD, adrenaline; AH, articaine hydrochloride; Max, maxillary; MH, mepivacine hydrochloride; N/A, not available; NRS, numerical rating scale; VAS, visual analog scale; WBFPS, Wong Baker facial pain rating scale.

Fig. 3. Intra-septal injection was performed on the mesial aspect of the right maxillary first molar.

bone and continues to the cancellous bone surrounding the tooth [11,12,16,18,19,43]. This technique is similar to the periodontal ligament (PDL) injection, which is also useful in providing osseous and soft tissue anesthesia and hemostasis for periodontal curettage and surgical flap procedures [2].

Previous studies by Malamed [2] and Saadoun and Malamed [11] described IS as injection into the buccal tissue located at the center of the interdental papilla with equal distance from the adjacent teeth. The needle should be inserted enough to penetrate the porous crestal bone and rigid enough to prevent bending during injection. The needle should be parallel to the long axis of the tooth. Consistent with a previous report by Woodmansey [44], the needle first enters the soft tissue and is injected until it contacts the underlying bone, and then slowly inserted into the interdental septum. The anesthetic solution is deposited through the medullary bone and absorbed into general circulation. Woodmansey [44] also recommended injecting at the mesial and distal aspects of the tooth to achieve anesthesia. In contrast, Reader et al. [8] suggested an injection site distal to the tooth for better anesthesia, except for the second molars, which should be injected at the mesial aspect of the tooth. Malamed [2] also suggested that 0.2–0.4 ml of anesthetic solution should be slowly diffused for successful IS.

Successful IS provides [8,11,14] a rapid onset of anesthesia, less tissue trauma, and requires a minute volume of anesthetic per dose. Previous studies on the duration and efficacy of anesthesia following IS are limited. Consequently, multiple tissue punctures may be repeated for a long procedure [2,14]. Biocanin et al. [16] demonstrated that the duration of anesthesia in IS increased in a dose-dependent manner. They reported that the duration of anesthesia using 0.8 ml of articaine in pulpal and soft tissues at 24.2 ± 17.0 and 70.0 ± 18.1 min, respectively.

The pinprick test by Brkovic et al. [43] evaluated the

Table 2. Studies involving injection pain produced by palatal infiltration

Author	Year	Sample size	Age (mean) (years)	Teeth	Anesthetic solution	Volume (ml)	Assessment tool	Mean pain score (SD)	Pain level
Saadoun & Malamed [11]	1985	100	N/A	Max. teeth	2% Lidocaine 1:50,000AD	N/A	N/A	N/A	no pain = 52% discomfort = 21% pain = 27%
Doman [12]	2011	113	7-81 (45.3)	Mand. premolar, molar	4% Articaine 1:100,000AD	0.4	VAS	N/A	pain-free = 62% very minor pain = 20%
Gazal, et al. [13]	2020	40	18-70 (36±13)	Mand. molar	2% Lidocaine1:100,000AD	0.8	100-mm VAS	16 (19.8)	mild pain

AD, adrenaline; Mand, Mandible; Max, maxillary; N/A, not available; VAS, visual analog scale.

Table 3. Studies involving anesthetic efficacy of maxillary buccal infiltration alone or with palatal infiltration for extraction or surgical removal

Author	Year	Sample size	Age (mean) (years)	Teeth	Treatment	Tooth condition	Anesthetic technique	Anesthetic solution	Volume (ml)	Waiting time (min)	Evaluation method	Success rate (%)
Isik, et al. [52]	2011	45	15-76 (N/A)	Max. teeth	Ext	N/A	MBI	4% Articaine 1:100,000AD	1.7	5	NRS	100
Kanaa, et al. [54]	2012	100	16-62 (33.4 ± 10.6)	Max. premolar, 1st molar	Ext	Irreversible pulpitis	MBI	4% Articaine 1:100,000AD 2% Lidocaine 1:80,000AD	2 2	5	HP-VAS	86.8 82.9
Sharma, et al. [55]	2014	80	18-67 (38.7 ± 12.7)	Max. premolar, molar	Ext	N/A	MBI	4% Articaine 1:100,000AD	0.9	5	HP-VAS	M1 – 83.33 M2 – 93.33 M3 – 100
Lima-Junior, et al. [56]	2009	100	15-46 (N/A)	Max. 3rd molar	Surgical removal	Impacted	MBI	(1,2) 4%AH 1:100,000AD (3,4) 4%AH 1:200,000AD	1.8	(1) 5 (2) 10 (3) 5 (4) 10	Presence/ absenceofpain	(1) 86 (2) 98 (3) 78 (4) 82
Lima, et al. [57]	2013	30	15-46 (N/A)	Max. 3rd molar	Surgical removal	Partially impacted	MBI	4% Articaine 1:100,000AD 4% Articaine 1:200,000AD	1.8 1.8	5	Need supple-mental PI	100 80
Uckan, et al. [34]	2006	53	18-48 (41.54)	Max. teeth	Ext	N/A	MBI MBI + PI	4% Articaine 1:100,000AD	2 1.75 + 0.25	5	VAS, FPS	96.8 97.5
Peng, et al. [16]	2008	104	18-56 (42.4)	Max. teeth	Ext	N/A	MBI MBI + PI	4% Articaine 1:100,000AD 4% AH+2% LH1:100,000AD	1.7 1.7 + 0.25	5	VAS	96.15 97.12
Hong, et al. [17]	2008	28	18-43 (27.4)	Max. 3rd molar	Ext	N/A	MBI MBI + PI	4% Articaine 1:100,000AD	1.5 1.7 + 0.4	5	VAS	82.14 92.86
Fan, et al. [35]	2009	71	17.5-67 (25.37)	Max. teeth	Ext	N/A	MBI MBI + PI	4% Articaine 1:100,000AD	1.7 1.7 + 0.4	5	VAS, VRS	95.77 97.18
Somuri, et al. [48]	2013	30	10-30 (17.73 ± 4.3)	Max. premolar	Ext	Orthodontic teeth	MBI MBI + PI	4% Articaine 1:100,000AD 2% Lidocaine1:100,000AD	1.7 1.75 + 0.25	N/A	FPS, VAS	90 100
Luqman, et al. [60]	2015	194	20-60 (41.1 ± 13.6)	Max. teeth	Ext	N/A	MBI MBI + PI	4% Articaine 1:200,000AD 2% Lidocaine1:100,000AD	1.7 1 + 0.2-0.4	*	FPS, VAS	84 100

AD, adrenaline; AH, articaine hydrochloride; Ext, extraction; FPS, faces pain scale; HP-VAS, Heft-Parker visual analog scale; LH, lidocaine hydrochloride; M1, first molar; M2, second molar; M3, third molar; Max, maxillary; MBI, maxillary buccal infiltration; N/A, not available; NRS, numerical rating scale; PI, palatal infiltration; VAS, visual analog scale; VRS, verbal rating scale.

*Depending on time to anesthesia on probing of palatal mucosa

duration of complete anesthesia with buccal and palatal anesthesia at 90 and 60 mins, respectively. However, there have been no previous studies on IS following MBI. A previous study by Ramirez et al. [45] suggested an interdental or intrapapillary injection (II) technique for MBI. Although there is a recommendation in pediatric dentistry for providing II for reducing pain in the palatal area, there has never been a report regarding its anesthetic

Table 4. Randomized controlled trials involving pulpal anesthetic efficacy of maxillary buccal infiltration alone or with palatal infiltration for endodontic treatment

Author	Year	Sample size	Age (mean) (years)	Teeth	Treatment	Tooth condition	Anesthetic technique	Anesthetic solution	Volume (ml)	Waiting time (min)	Evaluation method	Success rate (%)
Gross, et al. [49]	2007	65	18-26 (24)	Max. incisor, 1st molar	None	Healthy teeth	MBI	0.5% Bupivacaine 1:200,000AD 2% Lidocaine 1:100,000AD	1.8	3min / cont.in 3-min cycles for 120 min	EPT	64 82
Mikesell, et al. [6]	2008	96	21-43 (26)	Max. teeth	None	Healthy teeth	MBI	2% Lidocaine 1:100,000AD	1.8 3.6	3min / cont.in 3-min cycles for 60 min	EPT	100 97
Evans, et al. [7]	2008	40	20-33 (24)	Max. 1st molar	None	Healthy teeth	MBI	4% Articaine 1:100,000AD 2% Lidocaine 1:100,000AD	1cart	1min / cont.in 3-min cycles for 60 min	EPT/VAS	78 72.5
Mason, et al. [5]	2009	30	19-43 (25)	Max. incisor, 1st molar	None	Healthy teeth	MBI	2% Lidocaine 1:100,000AD 2% Lidocaine 1:50,000AD 3% Mepivacaine	1.8	1min / cont.in 3-min cycles for 60 min	EPT	97 93 93
Katz, et al. [50]	2010	60	22-31 (25)	Max. incisor, 1st molar	None	Healthy teeth	MBI	2% Lidocaine 1:100,000AD 4% Prilocaine 1:100,000AD 4% Prilocaine 1:200,000AD	1.8	1min / cont.in 3-min cycles for 60 min	EPT	83 80 93
Guglielmo, et al. [4]	2011	40	22-32 (25)	Max. 1st molar	None	Healthy teeth	MBI MBI + PI	2% Lidocaine 1:100,000AD	1.8 + mock 1.8 + 0.5	5min / cont.in 4-min cycles for 60 min	EPT	88 95
Srinivasan, et al. [51]	2009	40	18-40 (29)	Max. premolar, 1st molar	Access cavity	Irreversible pulpitis	MBI	4% Articaine 1:100,000AD 2% Lidocaine1:100,000AD	1.7 1.7	5	VAS	100, 100 80,30 (premolar, molar)
Hosseini, et al. [52]	2016	50	>18 (N/A)	Max. molar	Access cavity	Irreversible pulpitis	MBI	4% Articaine 1:100,000AD 2% Lidocaine 1:80,000AD	1.8	5	HP-VAS	66.67 56.52
Aggarwal, et al. [3]	2011	94	21-39 (31)	Max. 1st molar	Access cavity	Irreversible pulpitis	MBI MBI + PI	2% Lidocaine 1:200,000AD	1.8 1.8 + 0.5	15	HP-VAS	54 70

AD, adrenaline; EPT, electric pulp testing; HP-VAS, Heft-Parker visual analog scale; Max, maxillary; MBI, maxillary buccal infiltration; N/A, not available; PI, palatal infiltration; VAS, visual analog scale.

efficacy in operative and endodontic procedures [24,46]. The difference in technique of II was that the needle was inserted into the buccal papilla above the interdental septum without bone contact, whereas IS penetrated the crestal bone. Previous studies (Table 2) mentioned the pain experienced as ranging from no pain to mild pain when the IS injection technique is used. However, only one previous study has evaluated injection pain in permanent maxillary teeth [11].

FACTORS AFFECTING THE SUCCESS OF PULPAL ANESTHESIA IN MAXILLARY TEETH

1. Administration technique

Previous studies [26,29,47] have stated that the anesthetic success rate when MBI is employed ranges from 30 to 100%. Therefore, pulpal anesthesia may depend on the pulp status, anesthetic solution, injection technique, and measurement methods (Tables 3 and 4). MBI is a common maxillary tooth anesthetic technique used in teeth with uninflamed pulp [4-7,48-50]. Anesthetic efficacy decreases in teeth with irreversible pulpitis. A previous study by Srinivasan et al. [51] showed only a 30% anesthetic success rate after MBI with lidocaine in teeth with irreversible pulpitis. Aggrawal et al. [3] also reported a 54% anesthetic success rate of MBI in inflamed maxillary first molars. Hosseini et al. [52] also reported relatively low anesthetic success rates of 66.67% and 56.62% with articaine and lidocaine, respectively, in inflamed maxillary molars.

Previous studies have shown that PI, when used with

Table 5. Studies involving anesthetic efficacy of intraseptal injection for extraction or other treatments

Author	Year	Sample size	Age (mean) (years)	Teeth	Treatment	Tooth condition	Anesthetic technique	Anesthetic solution	Volume (ml)	Waiting time (min)	Evaluation method	Success rate (%)
Brkovic, et al. [43]	2010	35	(37 ± 12.3)	Max. lateral incisor	Ext	unrestorable or failure ornon-vitalteeth	IS or PLA as primary injection	2% Lidocaine 1:100,000AD	0.2 x 4 (MB, DB, MP, DP)	20 sec	VAS	IS – 88.6 PLA–91.4
Doman, [12]	2011	113	7-81 (45.3)	Mand. premolar, molar	Restorative treatment	N/A	IANB + IS	4% Articaine 1:100,000AD	N/A + 0.4	N/A	VAS	87
Gazal, et al. [13]	2020	200	18-65	Mand. molar	Ext or endodontic treatment	N/A	IANB + BNB supplement with IS or BI	2% Lidocaine 1:100,000AD 2% LH1:10^5AD for IS or 4% AH1:10^5AD for BI	1.8 + 0.9 IS–0.8 BI–N/A	10 min 20sec10min	HP-VAS	37.5 75 62.5

AD, adrenaline; AH, articaine hydrochloride; BI, buccal infiltration; BNB, long buccal nerve block; DB, distobuccal; DP, distopalatal; Ext, extraction; HP-VAS, Heft-Parker visual analog scale; IANB, inferior alveolar nerve block; IS, intraseptal injection; LH, lidocaine hydrochloride; Max, maxillary; Mand, mandibular; MB, mesiobuccal; MP, mesiopalatal; N/A, not available; PLA, periodontal ligament anesthesia; VAS, visual analog scale.

MBI for maxillary molars can increase pulpal anesthetic efficacy during treatment [3,4]. A study by Aggarwal et al. demonstrated that PI with 0.5 ml lidocaine could increase anesthesia from 54% (MBI) to 70% (MBI with PI) [3]. In addition, Guglielmo et al. reported that the addition of 0.5 ml lidocaine administered via PI improved the anesthetic efficacy of MBI from 88% to 95% [4]. However, Aggarwal et al. [3] reported that no injection technique resulted in 100% pulpal anesthetic efficacy in maxillary first molars with irreversible pulpitis. Moreover, PI can also provide palatal soft tissue anesthesia often accompanied by discomfort and pain in patients.

Pulpal anesthesia using IS has a success rate of approximately 30–90% [12,13,16-20, 43] (Tables 5 and 6). There are still insufficient studies on pulpal anesthesia in maxillary teeth [12,13,16-20]. Moreover, the comparison of anesthetic efficacies between MBI with PI and MBI with IS in maxillary teeth may be useful in determining which technique should be employed during routine dental procedures. This will depend on: 1) pulpal and periodontal diagnosis of the tooth and type of treatment procedure, 2) type and mechanism of action of the local anesthetic, 3) quantity of anesthetic solution to be deposited, and 4) concentration of epinephrine as a vasoconstrictor to be used.

2. Diagnosis of the tooth and type of treatment procedure

Previous studies have investigated and reported anesthetic efficacy from MBI, PI, and IS in various treatments (Tables 3, 4, and 5). Most previous studies involved permanent teeth extraction using MBI and PI, which provided high success rates ranging from 80 to 100% [34,35,48,53-60]. EPT testing of MBI reveals a high anesthetic success rate of 64-100% [4-7,49,50]. For complicated dental treatments, several authors have reported lower success rates for pulpal anesthesia [3,51,52]. Sinivasan et al. [51] reported a 30% anesthetic success rate in maxillary molars and 80% anesthetic success rate in maxillary premolars after MBI in endodontic treatment of teeth with irreversible pulpitis. Hosseini et al. [52] mentioned that anesthetic success rate was at 56.52% in the lidocaine group and 66.67% in the articaine group in maxillary first molars with irreversible pulpitis.

Additionally, another study by Aggarwal et al. [3] evaluated the anesthetic efficacy of lidocaine in maxillary first molars with irreversible pulpitis and found a 54% anesthetic success rate in MBI only, while a 70% anesthetic success rate was observed in MBI with PI. In a study by Guglielmo et al., MBI with PI increased pulpal anesthetic success rate from 88% to 95% when using lidocaine in maxillary teeth with irreversible pulpitis [4]. No technique has a 100% anesthetic success rate in maxillary first molars with irreversible pulpitis. A range of 28–90% anesthetic success rate was reported for pulpal anesthesia using IS [12,13,16-20,43], depending on: 1) the procedure done, such as extraction, restoration, or

Table 6. Studies involving pulpal anesthetic efficacy of intra-septal injection for endodontic treatment

Author	Year	Sample size	Age (mean) (years)	Teeth	Treatment	Tooth condition	Anesthetic technique	Anesthetic solution	Volume (ml)	Waiting time (min)	Evaluation method	Success rate (%)
Biocanin, et al. [16]	2013	180	24-31 (27.8 ± 9.9)	Mand. first premolar	None	Healthy teeth	IS with CCLAD	4% Articaine 1:100,000AD	0.4 0.6 0.8	2-min interval	EPT	73 90 90
Pandrangi [17]	2015	100	19-43 (25.2)	Mand. premolar, molar	None	Healthy teeth	IS with CCLAD as primary injection	4% Articaine 1:100,000AD 2% Lidocaine 1:100,000AD	0.7 + 0.7 (M + D)	1min / cont. in 2-min cycles for 60 min	EPT/ HP-VAS	AH: M1 – 35 M2 – 32 P2 – 34 LH: M1 – 28 M2 – 30 P2 – 26
Bonar, et al. [18]	2017	100	19-43 (25)	Mand. 1st molar	None	Healthy teeth	IS with CCLAD as primary injection	4% Articaine 1:100,000AD 2% Lidocaine1:100,000AD	0.7 + 0.7 (M + D)	1min / cont. in 4-min cycles for 60 min	HP-VAS	32 30
Webster, et al. [19]	2016	100	18-65 (34)	Mand. posterior teeth	Endodontic access	Symptomatic irreversible pulpitis	IANB + BNB + IS with CCLAD as supplemental injection	2% Lidocaine 1:100,000AD + 4% Articaine 1:100,000AD	1.8 + 0.9 0.7 + 0.7 (M + D)	15 min	HP-VAS/ VAS	IANB-25 IS-29
Dianat, et al. [20]	2019	90	18-65 (32.93 ± 10.67)	Mand. molar	Endodontic access	Symptomatic irreversible pulpitis	(1) IANB (2) IANB+BI (3) IANB+BI, IS	(1) 2% LH 1:100,000AD (2) 2% LH + 4%AH 1:105AD (3) 2% LH + 4%AH 1:105AD	(1) 1.7 (2) 1.7 + 1.7 (3) 1.7 + 1.7 + (0.85 x 2)	10 min	VAS, EPT	(1) 30.33 (2) 66.66 (3) 80.88
Gazal, et al. [13]	2020	200	18-65	Mand. molar	Ext or endodontic treatment	N/A	IANB + BNB supplement with IS or BI	2% Lidocaine 1:100,000AD 2% LH1:10^5AD for IS or 4% AH1:10^5AD for BI	1.8 + 0.9 IS–0.8 BI–N/A	10 min 20 sec 10 min	HP-VAS	37.5 75 62.5

AD, adrenaline; AH, articaine hydrochloride; BI, buccal infiltration; BNB, long buccal nerve block; CCLAD, computer-controlled local anesthesia delivery; D, distal; EPT, electric pulp testing; Ext, extraction; HP-VAS, Heft-Parker visual analog scale; I2, lateral incisor; IANB, inferior alveolar nerve block; IS, intraseptal injection; LH, lidocaine hydrochloride; M, mesial; M1, first molar; M2, second molar; Mand, mandibular; N/A, not available; P2, second premolar; VAS, visual analog scale.

EPT test, 2) the location of teeth in the jaw, and 3) type of anesthetic used. There is still no study comparing different treatment procedures between MBI with PI versus MBI with IS in permanent maxillary molars during restorative dental procedures.

In conclusion, pulpal anesthetic efficacy decreases in teeth with irreversible pulpitis. [61,62]. There is no ideal technique that achieves complete pulpal anesthesia for all dental procedures [3]. Moreover, only a few studies were made on pulpal anesthesia in maxillary permanent teeth [11,43].

3. Type and mechanism of local anesthetic

Lidocaine sets the gold standard in dental local anesthetics and has been compared to other types [2,63]. Articaine is a unique amide local anesthetic containing the same basic structural characteristics as other amides but with some unique features, such as the thiophene group, which has become increasingly popular in modern dentistry [64-67]. Articaine has a high affinity for plasma binding proteins, increases local anesthesia, hydrolyzes blood esterases, and quickly breaks down into inactive metabolites, which in turn are excreted through the kidneys with a decreased risk of systemic toxicity.

Articaine is safe and effective in adults. However, it should be carefully administered in children under the age of four due to the lack of clinical evidence on its use in children [68]. Nevertheless, Wright et al. [69] showed that articaine can be safely used in children under the age of four. In addition, Leith et al. [67] reported on the use of articaine in children. Prolonged numbness, an effect of articaine which can cause anxiety in children, has not been reported. Table 3, 4, 5, and 6 compares the anesthetic efficacy of articaine and lidocaine. In a previous study by Sharma et al. [55], Evan et al. [7], Hosseini et al. [52], Brandt et al. [70], and Srinivasan et al. [51], MBI technique using articaine fared better than lidocaine in the maxillary teeth. In addition, these authors suggested that articaine was superior to lidocaine as a local anesthetic.

4. Quantity of anesthetic solution and Concentration of a vasoconstrictor (epinephrine)

Previous studies have shown that an increased quantity of deposited anesthetic can improve the effectiveness of MBI [6,71], whereas a previous study reported no significant difference in the quantity administered [72]. Mikesell et al. [6], Brunetto et al. [71], and Shalash et al. [72] also compared the quantity of anesthetic solution in MBI, with no statistically significant difference. The study by Biocanin et al. [16] also found no significant difference in pulpal anesthetic efficacy of IS when the quantity of anesthetic solution deposited increased.

Vasoconstrictors in local anesthetics, such as epinephrine, may reduce blood loss during surgical procedures and increase the duration of anesthesia [73]. Previous studies on maxillary injections by Lima-Júnior et al. [56], Lima et al. [57], and Mason et al. [5] studied articaine with both concentrations of epinephrine routinely used in dentistry (1: 100,000 and 1: 50,000 epinephrine).

AGE OF PATIENTS

1. Pulp difference between young and aged permanent teeth

The young pulp consists of loose connective tissue, highly cellular pulp, and a rich vascular and nerve supply that reaches the pulpal horn. In contrast, aged pulp shows signs of atrophy, fibrosis, and dystrophic calcifications, as well as smaller pulp chambers, fewer stem cells, and degeneration of odontoblasts [74-78]. Studies by Bernick [75] and Bernick and Nedelman [76] defined the pulp difference between young and aged permanent teeth wherein the aged pulp group may experience a decrease in tooth sensitivity. Michaelson and Holland [77] assumed that young teeth with high innervation would be highly sensitive and that only minor damage and inflammation would impair their responses. Morse et al. [78] reported that physiological dentinogenesis of odontoblasts reduces the size of the pulp chamber, affecting pulpal anesthetic performance.

2. Bone difference child versus adult

Previous studies reported that the maxillary cortical bone is normally thinner than the mandibular cortical bone [22,79-83]. Ono et al. [80] used cone beam computed tomography to measure cortical bone thickness in patients aged 13–48 years in the buccal posterior region. Sathapana et al. [81] showed that age had a minor impact on alveolar cortical bone thickness. Studies by Ono et al. [80], Cassetta et al. [22], Fayed et al. [82], Swasty et al. [83], and Robert et al. [23] reported that the maxillary cortical bone is thinner than the mandibular cortical bone. Moreover, bones of children are less dense and more porous than bones of adults. In conclusion, the less dense the cortical bone the child has, the easier it is for the anesthetic to infiltrate into the bone compared to anesthetic infiltration into the denser cortical bone of adults.

SENSIBILITY TEST

There are two major types of dental pulp testing: vitality test and sensibility test. The vitality test assesses the blood supply present in the pulp by Laser-Doppler flowmetry, pulse oximetry test, or thermography; whereas, the sensibility test examines the ability of nerve fibers in the dental pulp to discern thermal and electric stimulation [84-86].

1. Cold thermal testing

Thermal testing is the most commonly used method for pulp testing. Cold thermal testing causes rapid contraction of dentinal fluid within the dentinal tubules when cold stimulus is applied to the tooth. [87,88]. There are currently many types of cold tests available.

1) Ice is the simplest cold testing agent that is easy to prepare.
2) Refrigerant spray is widely used in clinical settings due to its relatively cheap cost and its simple application technique. Different refrigerant sprays that are available in the market may be based on dichlorodifluoromethane (DDM), tetrafluoroethane (TFE), or a propane–butane mixture [86].

DDM is effective for cold testing and can produce a temperature of -50°C but has decreased in popularity [89]. TFE has been used to replace DDM. It produces a temperature of -50°C and is easy to use with rapid results [90]. Cold thermal testing from a previous article was studied by Cohen and Hargreaves [91]. Chen and Abbott, along with other researchers, have also studied the accuracy, reliability, and repeatability of other cold thermal testing agents, such as Endo-Frost®, frozen carbon dioxide (CO_2), effective cold stimulus as "CO_2 snow" or "dry ice", ice, and ethyl chloride [88,92,93] However, cold stimulants are effective and reliable only for assessing pulp vitality [94].

2. Electric Pulpal Tester

EPT uses a low-grade electric current on the tooth surface and causes ionic changes in the dentinal fluid within the tubules [89]. A positive result will cause local depolarization and the subsequent generation of an action potential from intact nerves [95]. Optimal EPT results are taken when the electrode tip is placed on the tooth surface adjacent to a pulp horn, the highest nerve density within the pulp [96]. Previous studies [97,98] suggest that even the least electric current can be used to stimulate the pulp and elicit a response. Lin et al. [98] reported that the lowest response for the maxillary first molars was obtained at the mesiobuccal cusp tip. Moreover, Kitamura et al. [99], Certosimo and Archer [100], and Reader et al. [8] suggested using the EPT to assess pulpal anesthesia prior to the commencement of dental procedures.

3. Limitations of sensibility testing

In young permanent teeth, there are several limitations regarding the use of sensibility tests. In EPT, a false negative response is obtained in vital teeth with incomplete root development, causing a higher threshold for testing [88,101-104]. Conversely, a false positive response is obtained in non-vital teeth with immature root formation [97,85].

ANXIETY AND PAIN ASSESSMENT IN CHILDREN

1. Anxiety assessment in children

Dental anxiety occurs as a response to dental treatment procedures and other related factors, such as age, parental/maternal anxiety, clinical environment, previous traumatic experience, and perceptions of an unsuccessful/painful treatment [105,106]. Scales used to measure dental anxiety are either reported by the observer or self-reported. Such scales include Frankl Category Rating Scale, Houpt Categorical Rating Scale, and Global Rating Scale (GRS). Self-reported scales include Dental Subscale of the Children's Fear Survey Schedule, Child Dental Fear Picture (CDFP), and Facial Image Scale (FIS) [107]. The FIS is used in children as young as 3 years old, is easy to understand, takes less than 1 min, and is commonly used for preoperative assessment [108].

Corah's Dental Anxiety Scale (CDAS) consists of four simple questions with five possible answers for a patient to select. Each answer is assigned a corresponding score, with the highest total possible score being 20. Scores within the ranges of less than 9, 9-12, 13-14 and 15-20 were interpreted as mild, moderate, high, and severe anxiety, respectively. The CDAS can be self-administered in the waiting room and requires only a few minutes [109].

2. Pain assessment in children

The International Association for the Study of Pain (IASP) defines pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.” [110]. Pain assessment in children depends on their cognitive development, clinical context, and pain typology [111].

Several pain measurements can be used in three main approaches of pain intensity: physiological, behavioral, and self-reported measures [112]. There are several self-reported pain intensity measures with well-established evidence of reliability and validity, such as the Faces Pain Scale and Faces Pain Scale-Revised, Oucher–Photographic or Oucher-numeric rating scale, Pieces of Hurt Tool, Visual Analog Scale, and WBS. WBS is the most widely-used scale [112].

The WBS is a horizontal scale of six line-drawn faces, ranging from a smiling face to a crying face, with ‘no hurt’ (score 0) on the left to ‘hurts worst’ (score 10) on the right [113]. It is also preferred by both children and practitioners when compared with other facial pain scales [114-116]. However, this scale can confound pain intensity, leading to misinterpreted results, especially in young children of 4-5 years old [113,117].

CONCLUSION

In conclusion, dental treatment of permanent maxillary first molars in children requires profound anesthesia, with no pain during injection, and should be considered in future studies. The dentist can use either maxillary buccal injection with palatal injection or maxillary buccal injection with intra-septal injection to achieve profound anesthesia. No singular technique is ideal for all dental procedures in permanent maxillary first molars of children.

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