RESEARCH PAPER

COMPARATIVE EVALUATION OF EFFICACY OF INTRA-LIGAMENTARY INJECTION USING ARTICAINE, KETOROLAC AND DEXAMETHASONE FOR REDUCTION OF ENDODONTIC PAIN IN SYMPTOMATIC IRREVERSIBLE PULPITIS – A RANDOMIZED DOUBLE BLINDED CLINICAL STUDY

Anuhya Samala[1*], Anisha Guntakandla[2], Jayaprada Reddy Surakanti[3], Anith kumar Chakilela[4], Ajay Chandra Vyas Goli[5], Sai Sri Rishi Annam[6], Hima Nandini Bura[7], Shruthi P[8]

[1*,3,4,5,6,7]Department of Conservative Dentistry and Endodontics, Kamineni Institute of Dental Sciences, Narketpally, Nalgonda, Telangana State, India. PINCODE: 508254

[2]Kamineni Institute of Medical Sciences, Narketpally, Nalgonda, Telangana State, India. PINCODE: 508254

[8]Government Medical College, Nalgonda, Telangana State, India. PINCODE: 508254

Corresponding Author E-MAIL: drsamalaanuhya@gmail.com

Abstract

Background: Dental pain significantly affects patients' quality of life and remains a primary concern in endodontic practice. The management of a "hot tooth", typically associated with Symptomatic Irreversible Pulpitis (SIP), is particularly demanding, as intense pulpal inflammation often compromises the success of conventional local anaesthesia. This randomized clinical study aimed to comparatively evaluate the effectiveness of intraligamentary administration of articaine, ketorolac, and dexamethasone in reducing intraoperative pain during endodontic treatment of mandibular molars diagnosed with SIP following an ineffective inferior alveolar nerve block (IANB).

Materials and Methods: A total of 30 adult patients presenting with SIP in mandibular molars were enrolled and randomly allocated into three equal groups (n = 10). All participants initially received an inferior alveolar nerve block using 1.8 mL of 2% lignocaine with 1:200,000 adrenaline. In cases where adequate pulpal anaesthesia was not achieved during access preparation, a supplemental intraligamentary injection was administered using a pressure syringe. Group A received articaine, Group B received dexamethasone, and Group C received ketorolac. Pain intensity was recorded using the Visual Analogue Scale (VAS) at predefined intervals, and heart rate variations were monitored to assess cardiovascular responses. Statistical analysis was conducted using appropriate parametric tests, with the level of significance set at $p < 0.05$.

Results:

All three groups demonstrated a statistically significant reduction in pain scores following intraligamentary injection ($p < 0.001$). The articaine group exhibited the greatest decrease in VAS scores, followed by dexamethasone and ketorolac groups. Intergroup comparison revealed a significant difference between articaine and ketorolac groups ($p < 0.05$), while the difference between articaine and dexamethasone groups was not statistically significant. Heart rate values remained within physiological limits across all groups, with no clinically relevant cardiovascular alterations observed.

Conclusion:

Supplemental intraligamentary injection significantly enhances anaesthetic success in mandibular molars with SIP when IANB alone is inadequate. Among the agents evaluated, articaine demonstrated superior anaesthetic efficacy, whereas dexamethasone and ketorolac may serve as useful adjuncts, particularly in cases associated with heightened inflammatory response.

Keywords:

Intraligamentary injection; Articaine; Ketorolac; Dexamethasone; Symptomatic irreversible pulpitis; Pulse oximeter; Midajet.

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Introduction

Effective pain control is essential for the success of endodontic procedures and is a decisive factor in shaping patient perception of dental care. Despite advances in local anaesthetic techniques, the management of acute pulpal pain particularly in mandibular molar teeth with symptomatic irreversible pulpitis (SIP) remains a considerable clinical challenge [1]. Patients with clinically diagnosed as *hot tooth* frequently continue to experience intra-operative discomfort even after a seemingly successful inferior

alveolar nerve block (IANB), which can complicate clinical management and heighten patient distress [2]. The limited efficacy of IANB in inflamed teeth is multifactorial. Reduced tissue pH in inflamed sites compromises the conversion of local anaesthetic molecules into their active base form, restricting membrane penetration. Furthermore, neurophysiological alterations such as the upregulation of tetrodotoxin-resistant sodium channels render inflamed pulpal nerves less responsive to conventional agents. Psychological influences, including heightened anxiety and reduced pain threshold, add another dimension to anaesthetic failure [3,4]. Clinical evidence indicates that in cases of symptomatic irreversible pulpitis, the efficacy of inferior alveolar nerve block (IANB) may be markedly reduced, with reported success rates ranging between 20% and 30%, thereby highlighting the necessity for adjunctive anaesthetic techniques [5].

Among adjunctive strategies, intraligamentary (IL) injection has shown favourable outcomes [6-8]. This technique delivers anaesthetic solution under pressure into the periodontal ligament, enabling diffusion into the cancellous bone and pulpal tissues. Success rates approaching 80–85% have been reported, especially when used in conjunction with conventional nerve blocks [9]. However, the effectiveness of IL injection varies with the pharmacological agent employed, and few investigations have compared the use of agents beyond traditional local anaesthetics.

Articaine, an amide anaesthetic with superior lipid solubility and bone penetration, has demonstrated promising results when delivered via IL injection, particularly in challenging pulpal conditions. Dexamethasone, a potent corticosteroid with anti-inflammatory properties, has been studied as a preoperative adjuvant capable of modulating inflammatory mediators and thereby enhancing anaesthetic action [10]. Ketorolac is a non-steroidal anti-inflammatory agent that exerts its analgesic effect through suppression of prostaglandin production. While its use as an oral premedication or via local infiltration has been investigated in recent literature, evidence supporting its efficacy when delivered as a sole intraligamentary injection remains scarce [11,12]. To the best of the available literature, randomized controlled clinical trials directly comparing articaine, dexamethasone, and ketorolac as intraligamentary supplements to inferior alveolar nerve block (IANB) in symptomatic mandibular molars are lacking. In response to this evidence gap, the present investigation sought to comparatively assess the effectiveness of these agents in alleviating intraoperative endodontic pain.

Materials and Methods

Study Design and Ethical Approval

A randomised, double-blind clinical trial was conducted in the Department of Conservative Dentistry and Endodontics at Kamineni Institute of Dental Sciences, Telangana, India. The study was approved by the Institutional Ethics Committee (KIDS/IEC/CONS/2022/20) and registered with the Clinical Trials Registry India (CTRI/2026/02/103066). Prior to participation, all eligible subjects provided written informed consent.

Sample Size and Eligibility Criteria

A schematic representation of the study methodology including patient recruitment, randomisation, group allocation, intervention procedures, and statistical analysis is presented in the CONSORT flow diagram (Figure 1). The sample size was calculated using the formula for comparing means, with Type I error set at 5% ($\alpha = 0.05$) and power at 90% ($\beta = 0.10$), based on standard deviation (0.40) and mean difference (0.36) values. The estimated minimum sample size was 27 participants per group, resulting in an overall sample size of 81 (27×3 groups).

Eighty-one patients (18–40 years) with permanent mandibular molars diagnosed with symptomatic irreversible pulpitis were recruited. Inclusion criteria included spontaneous and prolonged pain confirmed by cold and electric pulp tests, along with moderate to severe discomfort (VAS $\geq$ 5). Exclusion criteria included systemic illness, pregnancy or lactation, drug allergy, periodontal disease, root fractures, teeth with full coverage restorations, teeth with persistant pain post intra-ligamentary injection and multiple teeth with pain.

Randomisation and Blinding

Eligible participants were assigned to three study groups (n = 27 per group) through computer-generated random sequence allocation. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes. Blinding was implemented for both the operator and the patient with respect to the administered study medication (Figure 2).

- **Group A:** Intraligamentary articaine
- **Group B:** Intraligamentary dexamethasone
- **Group C:** Intraligamentary ketorolac

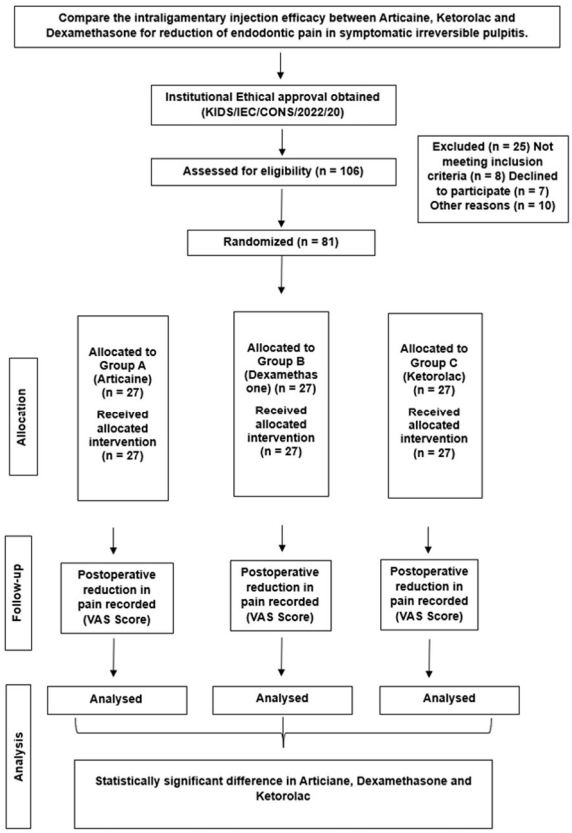


Figure 1. PIRATE FLOWCHART OF THE STUDY

Clinical Procedure

As part of the standardised anaesthetic protocol, all participants were administered an inferior alveolar nerve block using 1.8 mL of 2% lignocaine with 1:200,000 adrenaline. Following rubber dam isolation, access was initiated. Patients experiencing pain during caries removal or access cavity preparation were explained about the procedure, written informed consent was taken and they were administered the allocated sealed intraligamentary injection using a specialized pressure syringe (MIDAJET). The armamentarium used for intraligamentary injection and pain assessment are illustrated in Figure 3. At each site, the device was actuated three times, with each actuation delivering 0.2 mL of solution, resulting in a total of 0.6 mL administered at the mesiobuccal and distobuccal line angles (Figure 4).

Pain severity was assessed both before and after administration of the intraligamentary injection using a 10-point visual analogue scale (VAS) (Figure 5). Evaluate cardiovascular safety, heart rate was monitored continuously for a five-minute period following injection with the aid of a fingertip pulse oximeter (Figure 6).

If pain persisted, intrapulpal anaesthesia was administered as a rescue technique. Subsequent root canal procedures, including cleaning, shaping, and obturation, were completed in standard fashion.

Outcome Measures

The **primary outcome** was reduction in intraoperative pain as measured by VAS. The **secondary outcome** was variation in heart rate following intraligamentary injection.

Statistical Analysis

Statistical evaluation of the collected data was performed using SPSS software (version 26.0; SPSS Inc., Chicago, IL). Data distribution was assessed for normality using the Shapiro–Wilk test. Comparisons within groups were analysed using the paired *t*-test, while differences between groups were evaluated by one-way analysis of variance (ANOVA) with Bonferroni correction for post hoc comparisons. Statistical significance was set at $p < 0.05$.

Results

Patient Characteristics

All 81 enrolled patients completed the study (n=27 per group). The three groups were comparable at baseline with respect to age, sex, and preoperative pain scores ($p>0.05$).

Pain Scores

All groups demonstrated elevated preoperative pain scores, with mean VAS values of 8.11 (Group A), 8.81 (Group B), and 8.48 (Group C), and the intergroup comparison did not reveal a statistically significant difference ($p = 0.09$).

Following intraligamentary injection, all groups exhibited pain reduction; however, the degree of reduction varied significantly ($p<0.001$) (Table 1).

- **Articaine group (A):** Mean VAS decreased from 8.11 to 1.26 (mean reduction 6.85; p=0.007).
- **Dexamethasone group (B):** Mean VAS decreased from 8.81 to 2.81 (mean reduction 6.00; p=0.012).
- **Ketorolac group (C):** Mean VAS decreased from 8.48 to 4.44 (mean reduction 4.04; p=0.363).

Intergroup analysis demonstrated that Group A achieved a significantly greater reduction in pain scores when compared with both Group B and Group C ($p < 0.001$ for each comparison) (Graph 1). In

addition, Group B exhibited superior pain reduction relative to Group C, with the difference reaching statistical significance ($p < 0.001$).

Heart Rate Monitoring

Mean heart rate values remained stable across all groups during the 5-minute monitoring period. Intergroup comparisons at each interval revealed no statistically significant differences (p>0.05) (Graph 2). Within-group analysis showed only minimal fluctuations without clinical relevance (Table 2).

Figure 2. FILLED CARTRIDGES WITH THE THREE TEST DRUGS (BLINDED AS GROUPS A, B, C)

Figure 3. ARMAMENTARIUM (Intra-ligamentary injection Unit-MIDAJET, 30-G needle, finger pulse-oximeter, VAS scale, Rubberdam)

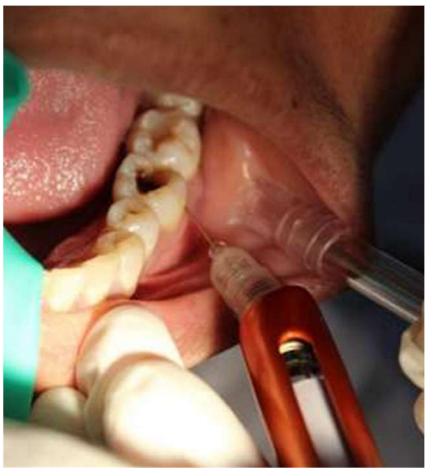


Figure 4. INTRALIGAMENTARY INJECTION SITE

Figure 5. PAIN LEVEL (VAS SCORE) – POST INTRALIGAMENTARY

Figure 6. FINGER PULSEOXIMETER READING FOR MEASURING HEART RATE

		Mean	N	Std. Deviation	Std. Error Mean	P Value	Mean difference
GROUP A	PRE-OP	8.11	27	1.340	.258		
	POST-OP	1.26	27	1.095	.211	0.007*	6.85±3.65
GROUP B	PRE-OP	8.81	27	1.178	.227		
	POST-OP	2.81	27	1.302	.251	0.012*	6±4.23
GROUP C	PRE-OP	8.48	27	1.014	.195		
	POST-OP	4.44	27	1.502	.289	0.363	4.04±3.65

*Paired T test

Table 1. WITHIN GROUP COMPARISON OF PAIN

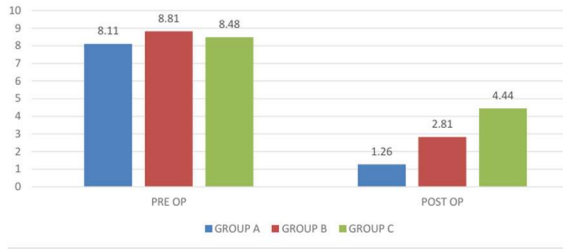
GROUPS		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	P Value	Mean difference
						Lower Bound	Upper Bound				
GROUP A	1min	27	76.851	4.80948	.92558	74.9493	78.7544	70.00	89.00		
	2 min	27	79.407	4.97114	.95670	77.4409	81.3739	71.00	90.00	0.45	
	3 min	27	79.814	5.38543	1.0364	77.6844	81.9452	71.00	92.00		2.63±0.65
	4 min	27	79.444	4.87800	.93877	77.5148	81.3741	72.00	92.00		
	5 min	27	79.481	4.70164	.90483	77.6216	81.3414	72.00	91.00		
	Total	135	79.000	5.00000	.43033	78.1489	79.8511	70.00	92.00		
GROUP B	1min	27	76.111	5.33013	1.0257	74.0026	78.2196	70.00	92.00		
	2 min	27	77.185	5.14435	.99003	75.1501	79.2202	71.00	92.00		
	3 min	27	77.481	5.33761	1.0272	75.3700	79.5930	71.00	92.00	0.98	1.11±0.23
	4 min	27	77.370	5.23412	1.0073	75.2998	79.4409	71.00	92.00		
	5 min	27	77.222	5.04848	.97158	75.2251	79.2193	71.00	91.00		
	Total	135	77.074	5.16537	.44456	76.1948	77.9533	70.00	92.00		
GROUP C	1min	27	77.037	4.08074	.78534	75.4228	78.6513	70.00	84.00		
	2 min	27	77.222	4.35301	.83774	75.5002	78.9442	70.00	86.00		
	3 min	27	77.444	4.04145	.77778	75.8457	79.0432	71.00	85.00	0.96	
	4 min	27	77.074	4.15031	.79873	75.4323	78.7159	70.00	85.00		0.11±0.234
	5 min	27	77.148	3.93899	.75806	75.5899	78.7064	71.00	86.00		
	Total	135	77.1852	4.05592	.34908	76.4948	77.8756	70.00	86.00		

*Repeated measures of Anova test

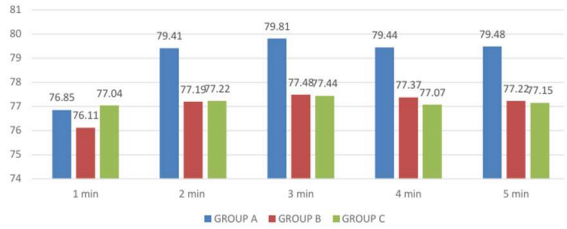
Table 2. WITHIN GROUP COMPARISON OF HEART RATE

Main Category	Technique
Local Infiltration Techniques	Supraperiosteal infiltration, Field block
Nerve Block Techniques	Inferior alveolar nerve block (IANB), Mental nerve block, Incisive nerve block, Long buccal nerve block, Gow-Gates block, Vazirani–Akinosi block
Supplemental Injection Techniques	Intraligamentary (Periodontal ligament) injection, Intraosseous injection, Intrapulpal injection
Topical Anaesthesia	Topical application of local anaesthetic agents

Table 3. CLASSIFICATION OF LOCAL ANAESTHETIC TECHNIQUES IN DENTISTRY (MODIFIED FROM MALAMED)



Graph 1: PAIN-BETWEEN GROUP



Graph 2. HEART RATE- BETWEEN GROUP

Discussion

Profound anaesthesia in mandibular molars with symptomatic irreversible pulpitis is difficult to achieve, as inferior alveolar nerve block (IANB) often exhibits reduced efficacy in inflamed pulpal tissues, with success rates of only 20–30%. [5] This has driven the need for effective supplemental techniques [13–15]. Among the available supplemental approaches (table 3), including intraosseous, intrapulpal, and intraligamentary injections, the intraligamentary technique has gained considerable clinical acceptance owing to its simplicity, minimal invasiveness and rapid onset of action. Unlike intraosseous injections, which necessitate cortical bone perforation, or intrapulpal injections, which require direct pulp exposure and may be associated with patient discomfort, intraligamentary injection can be readily administered through the periodontal ligament space with minimal tissue trauma [16]. The technique is believed to exert its effect by facilitating pressure-driven diffusion of the anaesthetic solution through the cribriform plate into the adjacent cancellous bone and marrow spaces, enabling rapid access to the apical region and pulpal nerve fibres, thereby achieving profound localised anaesthesia (figure 7).

In the present randomised trial, the addition of intraligamentary injection significantly enhanced pain control, with notable differences observed between the three tested agents. Pain reduction followed the order: Articaine > Dexamethasone > Ketorolac, and all three agents were well tolerated, with no adverse cardiovascular events or complications reported during the study. A total volume of 0.6 mL was selected to ensure adequate distribution of the anesthetic solution within the periodontal ligament space surrounding the involved root, thereby facilitating diffusion into the adjacent cancellous bone. This volume is consistent with previously published clinical trials, which have demonstrated improved anesthetic efficacy of supplemental intraligamentary injections with 0.6 mL compared with lower volumes, particularly in teeth with symptomatic irreversible pulpitis [17].

Among the agents, articaine demonstrated the greatest reduction in pain scores. Its enhanced performance can be attributed to its unique molecular structure, particularly the thiophene ring, which confers superior lipid solubility and facilitates better bone penetration. Existing literature suggests that articaine demonstrates superior anaesthetic efficacy compared with lidocaine in the management of *hot teeth*, particularly when administered via infiltration or the intraligamentary route [18]. This study's findings reinforce these observations, confirming articaine as a reliable option when conventional IANB alone is inadequate. Recent meta-analyses have further supported the superior performance of articaine for supplemental mandibular anaesthesia, noting higher pulpal anaesthesia success in inflamed tissues due to faster onset and enhanced diffusion across cortical plates [19].

Dexamethasone also proved effective, producing a significant reduction in intraoperative pain, albeit less than articaine. The mechanism likely stems from its ability to downregulate inflammatory mediators such as prostaglandins and cytokines, thereby reducing peripheral sensitisation and improving anaesthetic efficacy [20]. Previous investigations have highlighted

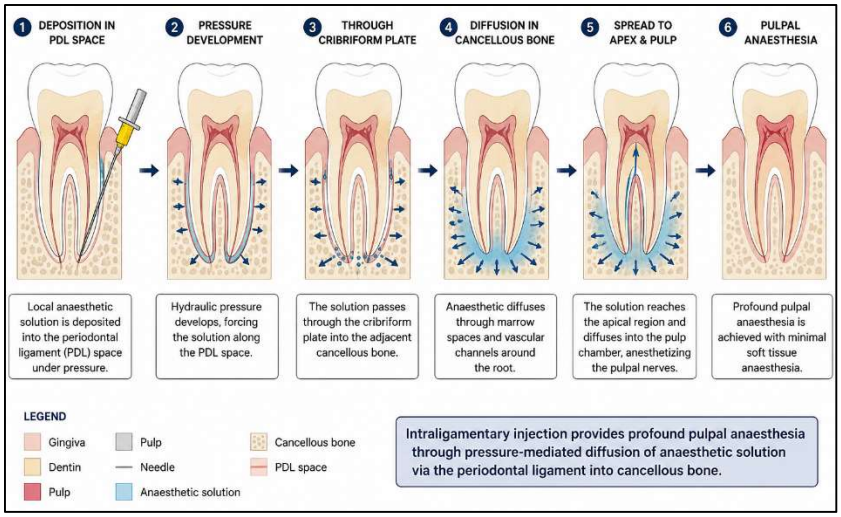


Figure 7. MECHANISM OF ACTION OF INTRALIGAMENTARY INJECTION

its role in decreasing postoperative pain when administered via periodontal ligament injection [21]. The present trial adds evidence to its intraoperative value, suggesting that dexamethasone may serve as a useful adjuvant in cases where inflammatory resistance hampers anaesthetic action. Recent clinical trials have shown that corticosteroid co-administration can significantly enhance the depth and duration of pulpal anaesthesia by stabilising neuronal membranes and attenuating prostanoid-mediated nociception [22]. Additionally, steroids may modulate tetrodotoxin-resistant sodium channels implicated in IANB failure, thereby improving responsiveness to local anaesthetics in inflamed molars [23].

Ketorolac showed the least reduction in pain scores, and the change was not statistically significant. Although NSAIDs effectively block cyclooxygenase pathways when administered systemically, their local anaesthetic-like properties remain questionable. It is possible that limited tissue diffusion or inadequate binding at nociceptor sites reduced its efficacy when delivered intraligamentarily. Previous reports on local ketorolac use are sparse and inconsistent, aligning with our findings that it is less predictable compared to established agents [24]. Pharmacokinetic studies suggest that ketorolac exhibits minimal peripheral nerve membrane stabilisation and relies heavily on systemic absorption for analgesic effect, reducing its utility when used locally in inflamed tissues [25]. A recent RCT comparing ketorolac infiltration with steroid-assisted blocks demonstrated significantly lower success, further supporting its limited role as a standalone intra-ligamentary agent [26].

The present study also highlights the clinical relevance of selecting an appropriate supplemental technique. IL injection provides rapid onset, minimal tissue distortion, and avoids additional nerve blocks, making it highly suitable for cases where immediate pulpal anaesthesia is required. Systematic reviews have now recognised intraligamentary injection as one of the most predictable adjuncts to IANB in symptomatic irreversible pulpitis, particularly when agents with high lipid solubility such as articaine are used [27]. Furthermore, the pressure-assisted delivery of anaesthetic solution into cancellous spaces may bypass inflamed neural pathways, contributing to the enhanced success observed with certain agents [28].

Safety Considerations

Heart rate monitoring revealed no clinically significant cardiovascular changes across groups, confirming the safety of intraligamentary administration of all three agents. This is consistent with earlier literature identifying the intraligamentary route as a well-tolerated, minimally invasive technique with transient and negligible systemic effects [29]. More recent evidence has reaffirmed that IL injection produces only short-lived haemodynamic responses, even in medically compromised patients, with cardiovascular parameters remaining within safe limits when delivered in controlled volumes [30].

Clinical Implications

The present findings have direct clinical significance. For patients with symptomatic irreversible pulpitis where IANB alone fails, intraligamentary administration of articaine provides the most effective supplemental anaesthesia. Dexamethasone may serve as an alternative when anti-inflammatory benefit is desired. Ketorolac, although safe, appears less suitable as a primary adjunct in such cases.

Conclusion

In mandibular molars affected by symptomatic irreversible pulpitis, the use of an intraligamentary injection as an adjunct to inferior alveolar nerve block has been associated with improved anaesthetic outcomes when primary block anaesthesia is inadequate. Articaine demonstrated the highest efficacy, dexamethasone provided favourable outcomes, while ketorolac showed limited benefit. All three agents were safe, with no adverse cardiovascular effects observed.

Clinical Relevance

Managing “hot tooth” cases remains a persistent challenge in endodontics. This study confirms that intraligamentary administration of articaine is the most effective supplemental strategy, while dexamethasone offers an anti-inflammatory advantage in selected patients. Ketorolac, though safe, is less predictable in local use. These findings can guide clinicians in choosing optimal adjunctive approaches for achieving reliable anaesthesia in difficult endodontic cases.

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