IEJ Iranian Endodontic Journal

Investigating the Association between the Presence of Pulp Stone and Anesthesia Failure in Upper and Lower Molar Teeth

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Article Type: **Original Article**

Received: 27 Feb 2026

Accepted: 21 Apr 2026

Published: 05 May 2026

Doi: *10.22037/iej.v21i1.46586*

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Abstract

Introduction: The close relationship between pulp stones in the pulp chamber and pulp neurovascular tissues suggests that the presence of pulp stones may compromise successful anesthesia. The present study assessed the effect of pulp stone presence on the failure of anesthesia in mandibular and maxillary molars. **Materials & Methods:** In this retrospective cohort study, 126 patients were studied. Pulp stones were diagnosed by periapical radiography. After the anesthetic agent injection, failure was defined as patients raising their hand upon experiencing pain during any procedural step of endodontic treatment. Furthermore, sound, eye, and motor (SEM) measures were used to assess the pain experience. In the case of either pain felt or the patients' demand, supplementary injections were made using the intraligamental technique. Multivariate logistic regression analysis was used to assess the effects of different variables on the success of anesthesia. **Results:** The overall prevalence of pulp stones in the patients was 59.5%, with 42.9% and 57.1% for males and females, respectively. The incidence of pulp stones in patients under the age of 40 was 54.7%, whereas in the ≥40 age group, it was 64.5%. The highest incidences of pulp stones were reported for maxillary second (42.9%) and first (21.4%) molars, followed by mandibular second (18.6%) and first molars (17.1%). Overall, the success rate of anesthesia was 55.6% for treated teeth. However, no significant differences were observed in the success rate of anesthesia regarding gender, tooth type, and pulp stone presence. Only the age group of patients significantly predicted the success of anesthesia (Odds ratio: 1.135; CI 95%: 1.43-6.76; *P*=0.004). **Conclusion:** Pulp stones had no significant effect on the success of anesthesia in mandibular and maxillary molars.

Keywords: Anesthesia Success; Pulp Stone; SEM (Sound, Eye, Motor)

Introduction

Successful anesthesia effectively prevents pain and restlessness during and after endodontic treatment and, as a result, reduces the stress and anxiety of the patient and the dentist [1]. In some cases, for instance, in mandibular molars, despite feeling lip numbness in mandibular molars, a patient may suffer from pain during endodontic treatment [2]. The success rate of local anesthetic injection depends on several factors, such as the condition of the pulp (the level of inflammation and infection, the presence of periapical disease, and even the mental state, as well as the age and gender of the patient) [3, 4].

Some of the causes of unsuccessful local anesthesia and the resultant pain during treatment include the anatomical differences in the nervous structure of the jaw and teeth, the patient's hypersensitivity, factors related to different techniques of anesthesia injection, the patient's stress and anxiety, and inflammation of the injection area [5]. One of these factors whose effect on the success of anesthesia has not been evaluated is the anatomical conditions of the teeth, such as calcified canals or pulp stones.

Pulp stones are calcified foci in the pulp or dentin area, as seen in the radiographs taken during routine patient visits [6]. These calcifications are diffused and surrounded by the pulp tissue or buried in the dentin structure [7, 8]. Pulp stones are mostly observed in the pulp chamber but may also be seen in the root and apical areas. The prevalence of pulp stones in molar teeth is higher than that of incisors and premolars, and they are higher in the maxillary teeth than in the mandibular teeth [9, 10]. Primary diagnosis of pulp stones is made in panoramic, periapical, and bitewing radiographs; however, lesions with a diameter of <200 µm cannot be identified in these radiographs [9, 11]. Due to less distortion and low magnification, bitewing radiography is more suitable for diagnosing pulpal lesions [12], and unlike two-dimensional radiographs, cone-beam CBCT is more effective in accurately diagnosing pulp stones with small diameters [13]. Vanessa et al. [14], using CBCT, reported a prevalence of 55% for pulp stones in a Brazilian population. Jannati et al. [15], in a systematic review of 14093 individuals, reported a prevalence rate of 36.53% for pulp stones.

Based on their size and location, pulp stones can challenge endodontic treatments, as they block access to the root canal orifice and result in complications for endodontic treatments [16]. Due to the relationship between pulp stones and nerve tissue and the possibility of the burial of some nerve cells in the pulp stone structure, some researchers claimed that these lesions can cause pain in patients [17]. The close relationship between pulp stone lesions and pulp neurovascular tissue raises questions about the relationship between these lesions and pain before and during endodontic treatment. Mousavi and Heshmat, in a study of the effect of pulp stones on the success of anesthesia in the maxillary molar teeth, reported presence of these stones has had a significant negative impact on pain during endodontic treatment [18]. However, their study had some methodological ambiguities in terms of performance and detection biases, and was only performed on the maxillary molar teeth. Therefore, this study aimed to investigate the association between the presence of pulp stones and anesthesia failure in upper and lower molar teeth with a more precise methodology. The null hypothesis was that the presence of pulp stone has no significant impact on anesthesia success rate in mandibular and maxillary molars.

Materials and Methods

All anesthetic injections and endodontic procedures were performed by a single experienced endodontist, thereby eliminating operator variability as a potential confounder. For mandibular molars, an inferior alveolar nerve block was first administered. After confirmation of lip numbness, a routine buccal infiltration using 4% articaine with epinephrine (1:200,000) was performed as a supplemental technique, based on evidence supporting improved anesthetic success in teeth with symptomatic irreversible pulpitis. Injection volumes, needle gauge (27-gauge), timing intervals, and waiting periods were standardized.

The research was conducted using a retrospective and observational cohort method. This study was approved by the Ethics Committee of the Kerman University of Medical Sciences (ethical code IR.KMU.REC.1401.543). The studied population included 126 patients referred to a private practice office of an endodontist. Based on a previous study [18] the sample size was calculated based on the rule of events per variable (EPV). We considered an EPV of 30 for logistic regression analysis, which yielded a sample size of 120 individuals [19].

Inclusion criteria

1. Adult patients (≥18 years) presenting with symptomatic irreversible pulpitis in upper or lower first or second molars.
2. Patients without known hypersensitivity to lidocaine, articaine, or epinephrine.
3. Patients classified as American Society of Anesthesiologists (ASA) physical status I or II.
4. Patients reporting a history of spontaneous pain and exhibiting a prolonged, intense response to cold vitality testing.
5. Patients with the ability to recognize and express the type and intensity of pain.

Exclusion criteria

1. Patients classified as ASA physical status III or IV
2. Presence of periodontal disease affecting the target tooth, including gingival recession, alveolar bone loss, or deep periodontal pockets.
3. Known allergy to the anesthetic agent used in the study.
4. Use of analgesics within 12 hours before treatment.
5. History of chronic alcohol/drug/psychotropic substance use.
6. Non-restorable tooth structure (e.g., severely compromised crown).
7. Presence of full-coverage restoration on the target tooth.
8. Clinical signs of acute infection, including swelling or sinus tract associated with the target tooth
9. Pregnancy or lactation.
10. Severe occlusal wear or structural loss, including absence of buccal or palatal cusps.
11. Third molars.
12. Teeth exhibiting partial pulp necrosis

Patients who were included in this study received either infiltration or inferior alveolar nerve (IAN) anesthesia for maxillary and mandibular molars, respectively. For both mandibular and maxillary molars, first, a topical gel of 20% benzocaine was used. One minute after topical anesthesia application, for mandibular molars, an IAN block was used with the direct technique. To this end, after touching the bone in the area, the injection needle was pulled back a little, and after performing aspiration, the injection was done in the desired place within 60 seconds. Ten minutes after the injection of the infra-alveolar nerve block, the patient was asked about the lip numbness, and if the anesthesia failed, the patient was excluded from the study due to the failure of the block anesthesia. Patients who reported lip numbness received a cartridge of 4% articaine solution with epinephrine 1:200000 (Dentacaine 200, Elixir, Borujerd Pharmaceutical Company, Iran) by an infiltration injection as a supplementary injection. After 5 minutes, a clamp and rubber dam were placed, and the classic access cavity of the desired tooth was prepared after caries removal.

The patient was asked to raise his hand if he felt pain while performing the procedural steps from the beginning of caries removal and entering the dentin, preparing the access cavity, entering the pulp, and entering the root canal. If the patient raised his/her hand, he/she was asked about the quality of pain and the need for supplementary anesthesia. In case the patient either felt moderate to severe pain or requested re-injection of anesthesia, supplementary anesthetic techniques were used, and anesthesia was considered unsuccessful. From the beginning of the preparation of the access cavity to the end of the preparation, the SEM (Sound, Eye, Motor) criterion was also used to evaluate the patient's pain during the procedure, i.e., apart from the expression of pain by the patient, any sound that could be heard from the patient (sound), changes in the movement of the eyelid and eye or the movement of his head and body was also considered a sign to stop the procedure and ask the patient to determine the severity of pain [20]. If the patient did not request supplementary anesthesia but SEM showed the possibility of pain and discomfort, they were again asked about the quality of pain and the need for supplementary anesthesia. If there was a positive SEM, anesthesia was considered unsuccessful.

In people who received mandibular block injection and buccal infiltration anesthesia but had pain during the preparation of the access cavity and dentin removal, intraligamental injection of 2% lidocaine with 1:80000 epinephrine with a needle head of #27 gauge and length of 25 mm (Spident-NOP-Korea) was performed by the same person who performed the inferior alveolar nerve block injection [21]. According to previous studies, the injection volume was 0.3 mL on each side [22].

If the patient did not report discomfort or pain after the supplementary injection into the ligament during the remaining procedural steps, and the findings of SEM also indicated the absence of discomfort and pain, the supplementary anesthesia was declared successful. The root length of the teeth that received intra-ligamental supplemental anesthesia was determined according to the length obtained from the Root ZX apex locator (ZX II-J Root, Morita Apex Locator) indicator in such a way that after preparing the access cavity and locating the root canal orifices with the #10 Mani K-file, the initial length of the root canals was determined, and the length of each root canal was recorded separately. Then, the files were placed in the root canals, and the length of the root canals was confirmed using digital radiography, RVG 5200 Carestream (Carestream, Canada). If there was a discrepancy, the length was determined again by the apex locator.

In the maxillary molars, a 1.8-mL cartridge of 2% lidocaine anesthetic solution with epinephrine (1:80000) (Darou Pakhsh, Tehran, Iran) was used. A topical anesthetic agent (benzocaine) was placed with an applicator on the mucosa of the injection site, and after one minute, an infiltration injection was performed. For this, a 27-gauge needle with a short length was placed in the alveolar mucosa diagonally to the bone until it was estimated that it was on the upper end of the buccal root of the tooth. Caries removal and access cavity preparation were undertaken five minutes after anesthesia and after isolating the tooth with a clamp and rubber dam.

After completing the access cavity preparation and identifying the root canal orifices, the rest of the endodontic procedures were the same as those for the mandibular molars.

The type of tooth, the success of primary anesthesia, and the need for supplementary anesthesia or the failure of anesthesia were recorded in a checklist by the researcher.

To determine the presence or absence of pulp stones, two dental providers other than the clinician who did the endodontic treatment examined the periapical radiographs of the patients. These two dental providers were not aware of the anesthesia outcome. At first, they observed 20 periapical radiographs for calibration, and then the periapical radiographs of the treated teeth were examined by two researchers separately and evaluated for the presence of pulp stones. Two weeks later, the same radiographs were reviewed again to ensure acceptable inter-observer calibration. This was performed blindly without any knowledge of the results of anesthetic procedures (success or failure). Then, the results of the presence or absence of pulp stones evaluated by each of the two researchers were compared, and in case of discrepancy, both researchers again viewed the conflicting radiographs together. If there was no agreement again, radiographs were referred to a third person to evaluate the presence or absence of pulp stones.

First, the frequencies and percentages of qualitative variables, including gender, age group, type of the examined teeth, the presence of pulp stones, and the success of either IAN block or infiltration anesthesia, were calculated and reported. Also, multivariate logistic regression analysis was used to determine the effects of different variables on the prognosis of success and failure of the infiltration technique. The Hosmer-Lemeshow test was used for assessing goodness of fit of the model. P value less than 0.05 was considered significant.

Results

Data related to the anesthesia of 126 patients were reviewed. Pulp stones were identified in 75 (59.5%) patients, with no pulp stones in 51 (40.5%) patients. On the other hand, anesthesia was successful in 70 patients (55.6%), but in 56 patients (44.4%), anesthesia failed.

Table 1 presents the frequencies of anesthesia success in the investigated sample by age group. The success rate of anesthesia in men was 58.8%, and in women, it was 53.3%. The anesthesia success rate based on the type of tooth has been shown in Table 2. Table 3 presents the anesthesia success rates based on the presence or absence of pulp stones. Table 4 shows that the presence of pulp stones was associated with a lower anesthesia success rate in both maxillary and mandibular molars, with a more pronounced reduction observed in mandibular molars.

Table 5 presents the results of the logistic regression analysis to determine the effects of different variables on the success of dental anesthesia. Only the age group had a significant role in determining the success of anesthesia (P=0.004); however, other variables, including gender (P=0.914), tooth type (P=0.563), and the presence or absence of pulp stone (P=0.223), did not have a significant role in this regard.

Fisher's exact test revealed no significant differences in the frequencies of pulp stones in the samples in terms of the age group (P=0.28). Therefore, the presence of pulp stones had no relationship with the age group of the samples.

Discussion

The results of the present study support the null hypothesis that the presence of pulp stone has no significant impact on anesthesia success rate, either in maxillary or mandibular molars. The results of the present study showed that only the age of the patients had a significant impact on anesthesia success.

A pulp stone is a focus of calcification in the dental pulp that can potentially interfere with endodontic treatments. On the other hand, there was a close relationship between the presence of pulp stones in the root canal and the neurovascular tissue of the pulp; as a result, it appears that the presence of pulp stones may challenge the achievement of successful anesthesia. However, the results of the present study showed that the presence of pulp stones did not affect the success of anesthesia in upper and lower molar teeth (P=0.33).

The relatively low overall anesthesia success rate (55.6%) should be interpreted in the context of symptomatic irreversible pulpitis, which is known to substantially reduce anesthetic efficacy. In addition, strict clinical criteria, including patient-reported pain, SEM indicators, and the need for supplementary anesthesia, were used, likely increasing the observed failure rate.

Although pulp stones may be located adjacent to neurovascular tissues, anesthetic failure in irreversible pulpitis is primarily driven by inflammatory mechanisms such as reduced tissue pH, altered sodium channel expression, increased nociceptor excitability, and impaired anesthetic diffusion. These mechanisms may outweigh any localized effect of pulp stones.

The findings should be interpreted within the broader literature on anesthetic failure mechanisms, including accessory innervation, anatomical variability, and calcification biology, rather than comparison with a single prior study.

Several variables seem to be effective in the success and failure of anesthesia. The length of the root of the tooth [23], the type of anesthetic solution [24], the type of tooth, and the anatomical location of the tooth [25] are among the factors that may be effective in the success of anesthesia.

In this study, the success rate of anesthesia in the age group of ≥40 years (67.7%) was significantly higher than in the age group of <40 years (43.8%). Segura-Egea et al. also showed that younger patients with irreversible pulpitis experienced more pain during treatment than older patients. Although in that study, 35 years of age was considered the cut-off point [25], in this study, 40 years of age was considered because the number of patients >40 and <40 years were much closer to each other. However, there was no significant difference in anesthesia success rate in male patients (58.8%) and female patients (53.3%) or in terms of tooth type (P=0.54 and P=0.68, respectively).

In the present study, mandibular block anesthesia and buccal supplemental anesthesia with articaine were used because it has been reported that this method is more successful than lidocaine for mandibular block injection [26].

Several investigations reported different success rates using various anesthetic solutions and techniques [27-29]. In the present research, the overall success rate was 55.6%, which is higher than several investigations [1, 30] while lower than others [27-29]. These differences can be caused by the type of anesthetic agent used, because lidocaine with 1:80000 epinephrine was used as the anesthetic solution for infiltration injection as well as IAN block. Other studies have reported a wide range of success rates

Table 1. Frequencies and percentages of anesthesia success in the samples according to their age group

Age group \ Success of anesthesia	Successful (%)	Unsuccessful (%)	Total (%)
<40	28 (43.8)	36 (56.2)	64 (100.0)
≥40	42 (67.7)	20 (32.3)	62 (100.0)
Total	70 (55.6)	56 (44.4)	126 (100.0)

Table 2. Frequencies and percentages of anesthesia success based on the tooth type

Tooth type \ Success of anesthesia	Successful (%)	Unsuccessful (%)	Total (%)
Maxillary second molar	30 (54.5)	25 (45.5)	55 (100.0)
Maxillary first molar	15 (65.2)	8 (34.8)	23 (100.0)
Mandibular first molar	12 (57.1)	9 (42.9)	21 (100.0)
Mandibular second molar	13 (48.1)	14 (51.9)	27 (100.0)
Total	70 (55.6)	56 (44.4)	126 (100.0)

Table 3. Frequencies and percentages of anesthesia success based on the presence or absence of pulp stones

Pulp stone \ Success of anesthesia	Successful (%)	Unsuccessful (%)	Total (%)
Absent	31 (60.8)	20 (39.2)	51 (100.0)
Present	39 (52.0)	36 (48.0)	75 (100.0)
Total	70 (55.6)	56 (44.4)	126 (100.0)

Table 4. Anesthesia success rate based on the presence or absence of pulp stone in maxillary and mandibular molars.

Tooth type \ Success of anesthesia			Successful (%)	Failure (%)
Pulp stone	**Maxillary molar**	**Absent**	19 (61.3)	12 (38.7)
		Present	26 (55.3)	21 (44.7)
	Mandibular molar	**Absent**	12 (60.0)	8 (40.0)
		Present	13 (46.4)	15 (53.6)

Table 5. The results of the multivariate logistic regression analysis in examining the effects of different variables on the success of anesthesia

Variables	B	S.E.	Adjusted odds ratio	P-value	95% Confidence interval
Age group (≥40 vs. < 40	1.135	0.396	3.11	0.004	1.43-6.76
Sex (male vs. female)	0.042	0.389	1.04	0.914	0.49-2.24
Tooth					
Second upper molar	0.581	0.510	1.79	0.255	0.66-4.68
First upper molar	0.788	0.618	2.20	0.202	0.66-7.38
First lower molar	0.660	0.621	1.94	0.288	0.57-6.54
Second lower molar	Reference	-	-	0.563	-
Pulp stone (presence vs. absence)	0.490	0.402	1.63	0.223	0.74-3.59

of maxillary and mandibular anesthesia. The reason for this difference might be the criteria for evaluating the success of anesthesia, the case population, or the study inclusion criteria [30, 31].

Anesthesia failure of molar teeth in clinical conditions occurs in about 15% of normal pulps and 44-81% of inflamed pulps [31], which are different according to anatomical variations, operator's technique, degree of inflammation, use of non-steroidal anti-inflammatory analgesics (NSAIDs) before administration of the anesthetic agent, and psychological reasons [1, 30].

Mousavi and Heshmat [18], in the study of the association between the presence of pulp stones and the success of local anesthesia showed that the anesthesia success rate in patients without pulp stones was 100%, whereas having pulp stones resulted in 74.3% anesthesia failure, indicating a significantly higher rate of anesthesia failure in molar teeth with pulp stones ($P<0.001$). In the present study, the presence of pulp stones did not significantly affect the changes in the rate of anesthesia failure. One of the reasons for the difference between these two studies was including both maxillary and mandibular molars in this study, while Mousavi and Heshmat examined only maxillary molars. On the other hand, in the study by Mousavi and Heshmat [18], the presence of pulp stones was confirmed only by the researcher who was also involved in endodontic treatment. In contrast, to avoid detection and performance biases, in this study, two researchers who were not involved in the treatment and were not aware of the outcome of anesthesia observed the radiographs separately to evaluate the presence or absence of pulp stones.

Since the aim of this study was to investigate the impact of dental pulp stone presence on anesthesia success, it is not possible to make the dental provider blind to the aim of the study. However, evaluating retrospective data may prevent performance and detection biases.

Mousavi and Heshmat [18] reported a 100% success rate of anesthesia in the maxillary molars without pulp stones, whereas in the present study, the success rate was 61.3% in maxillary molars without pulp stones. One of the reasons for this difference might be the method used during the procedural steps. In Mousavi and Heshmat's study, the success of anesthesia was first tested with an electric pulp tester (EPT), and in case of a positive response to the EPT, anesthesia was repeated and considered a failure. However, there was a possibility of a false-negative pulp response to EPT after administration of the anesthetic solution [1, 30]. Also, during procedural steps, Mousavi and Heshmat used VAS to evaluate pain during endodontic treatment; however, in the present study, in addition to rating patients' pain, SEM, as well as patients' requests for supplementary anesthesia, were also considered as anesthesia failure, which might cause a further increase in cases of failure. For this reason, the failure rate in the present study may be higher than in Mousavi and Heshmat's study.

One of the limitations of this study was determining the presence of pulp stone based on the periapical radiograph. If the patient had CBCT, the percentage of pulp stone may be higher (11). Radiographs are unable to identify small calcifications (<200 μm), which may result in non-differential misclassification. Such misclassification is expected to bias the observed association toward the null; therefore, a false-negative finding cannot be excluded. Accordingly, the present results apply only to radiographically detectable pulp stones.

On the other hand, the rate of anesthesia failure in maxillary molars with pulp stones in the present study was 38.7%, whereas Mousavi and Heshmat reported that 74.3% of patients exhibited failure in anesthesia in the same teeth.

Conclusion

Within the limitations of this retrospective study and the use of periapical radiography, no statistically significant association was observed between the presence of radiographically detectable pulp stones and anesthesia success in maxillary and mandibular molars. Given limitations related to imaging sensitivity, statistical power, and clinical variability, the possibility of a false-negative finding cannot be excluded.

Based on this and despite the slight reduction in the success rate of infiltration anesthesia in teeth with pulp stones, no significant differences were seen between teeth with and without pulp stones.

Acknowledgements

The present study was supported by the Kerman University of Medical Sciences. The author team thanked the mentioned authorities for their endless support.

Conflict of interest

None.

Funding support

None.

Authors' contributions

Conceptualization: MP, Methodology: MP/SG/HM/SK/NN, Formal analysis and investigation: MP/SG/SK/HM/NN, Writing original Draft: SG/MP, Writing review: SG/MP/HM, Editing, MP, Supervision: MP/HM. All authors read and approved the final manuscript

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Please cite this paper as: Parirokh M, Manochehrifar H, Nakahee N, Kakooei S, Ghadimi SH. Investigating the Association between the Presence of Pulp Stone and Anesthesia Failure in Upper and Lower Molar Teeth. Iran Endod J. 2026;21(1): e15. Doi: 10.22037/iej.v21i1.46586.