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Evaluation of the effects of calcium hydroxide-based, calcium silicate-based, and epoxy resin-based sealers on postoperative pain after a single session non-surgical endodontic retreatment: a randomized clinical trial

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Abstract

Objectives This randomized clinical trial aimed to evaluate the effect of calcium hydroxide-based, calcium silicate-based and epoxy resin-based root canal sealers on postoperative pain (PP) after a single session of non-surgical endodontic retreatment of the teeth with chronic apical periodontitis.

Materials and methods Ninety-six participants who had teeth with previously root canal treatment, asymptomatic, a single root and single canal, chronic apical periodontitis, were included in the study and then were randomly allocated to one of three experimental groups. ($n=32$ per group).An endodontic specialist performed same retreatment protocols in a single visit. Participants were asked to rate the intensity of PP on a visual analogue scale at 6, 12, 24, and 48 h, and 3, 4,5, 6, and 7 days, and to mark whether they had taken analgesic (400 mg Ibuprofen) during the same periods after retreatment. All statistical analyses were performed using a software program (IBM SPSS Statistics, Version 22), and the significance level was set at $P<0.05$.

Results There was no significant difference between the groups in PP and analgesic intake at any of the time intervals evaluated($P>0.05$).A strong positive correlation was observed at 48 h and 96 h when the correlation between PP and analgesic intake was evaluated regardless of the type of root canal sealer. PP level was associated with age, gender, Periapical Index (PAI) score, and jaw type.($P<0$ 0.05).

Conclusions Epoxy resin, Calcium silicate, and calcium hydroxide–based root canal sealers resulted in statistically similar postoperative pain levels.

Clinical significance Each of the epoxy resin, calcium silicate, and calcium hydroxide-based root canal filling materials could be used safely in patients when considering PP.

Trial registration ClinicalTrial.gov, NCT06803277, record date: 2025-01-17, retrospectively registered.

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Keywords Calcium hydroxide-based sealer, Calcium silicate-based sealer, Epoxy resin-based sealer, Endodontic retreatment, Postoperative pain

Introduction

The problem of PP following endodontic treatment continues to be one of the most significant clinical issues. This condition is not only a source of chronic discomfort for patients but is also a potential source of emergency room visits. The incidence of PP following endodontic treatment can range from 3% to 58% [1].

Root canal retreatment is recommended when endodontic disease persists or develops after root canal treatment. Root canal retreatment is believed to be the elimination of the main causes of treatment failure. In most cases, these are primary resistant or secondary invading microorganisms [2]. Favorable healing with high success and survival rates can occur with root canal retreatment. However, post-treatment complications such as PP have been observed after root canal retreatment [3]. These factors that cause PP include age, gender, single/multiple visits, analgesia use, periapical condition, tooth type, preoperative pain, instrumentation technique, and irrigation/filling protocol. The severity of the inflammatory response is influenced by the composition of the sealer and may be related to the PP that is experienced after endodontic therapy [4]. Root canal sealers can activate trigeminal nociceptors, and this, along with immune responses, can be the cause of pain and flare-ups [5].

Calcium hydroxide-based sealers (CHBSs) have been used for endodontic purposes for many years. CHBSs are known to have antibacterial properties by releasing hydroxyl ions and decreasing cytotoxicity as well as osteogenic and cementogenic potential [6]. The use of calcium silicate-based root canal sealers (CSBSs) has become very popular in recent years. CSBSs, just like CHBSs, have antibacterial properties by releasing hydroxyl ions and decreasing cytotoxicity as well as osteogenic and cementogenic potential. In addition, the calcium ions in the CSBS stimulate osteoblastic differentiation and bone formation [7]. Unlike epoxy resin sealers, which are prone to shrinkage during setting, bioceramic sealers have the capacity for expansion of up to 0.2% within the root canal space [8]. AH Plus (Dentsply, Maillefer, Ballaigues, Switzerland) is an epoxy resin-based root canal sealer as a gold standard. It has favorable physicochemical properties and good adaptability to root canal walls. Therefore, it is frequently used for comparison with other sealers [9].It has been found to release monomers such as bisphenol A diglycidylether (Bis-GMA), which can delay the healing process if exposed to the periapical tissues [10].

There is only one study evaluating the effect of root canal sealers on PP after non-surgical retreatment [11]. Although it is a very important issue, there is not enough clinical data available. This study aimed to evaluate the effect of calcium hydroxide-based, calcium silicate-based and epoxy resin-based root canal sealers on PP after a single session of endodontic retreatment of the teeth with chronic apical periodontitis. To the best of our knowledge, no study has evaluated the effect of these three different root canal sealers on PP after endodontic retreatment. The null hypothesis was that there are no significant differences between used root canal sealers in terms of PP levels and analgesic intake after endodontic retreatment.

Materials and methods

In this single-blinded randomized clinical trial, the Preferred Reporting Items for Randomized Trials in Endodontics 2020 guidelines were followed [12, 13](Fig. 1). The study protocol was registered in the www.clinicaltrials.gov database with identifier number (NCT06803277, Registration date: 2025/01/31). Based on information from a prior investigation [14], a minimum sample size calculation was performed using the G*Power 3.1 software with a power of 0.80 and an effect size of 0.40. The minimum total required sample size was 78 patients. To enhance the statistical power of the study and compensate for potential patient loss, A total of 96 patients were enrolled. ($n = 32$, for each group) The patients signed a written informed consent form.

This study is a single-center randomized controlled clinical trial. Before starting the study, the ethics approval was obtained from the Erciyes University Medical Faculty Ethics Institution, with decision number 2021/306. The study included 96 teeth of 96 patients who applied to the Department of Endodontics between June 2021 and November 2023 according to the following criteria. The criteria for inclusion and exclusion are shown below.

Inclusion criteria

Patients who did not have any systemic disease, pregnancy or breastfeeding, who were older than 18 years, who had not used analgesics, anti-inflammatories, or antibiotics in the last 7 days and cortisone in the last 6 months, who had improved communication skills and were at a mental level to express pain scoring clearly, who did not have bruxism problem or primary contact were included in the study. Teeth with root canal obturation 2 mm shorter than the WL have preoperatively asymptomatic (No pain on palpation and percussion, no mobility,

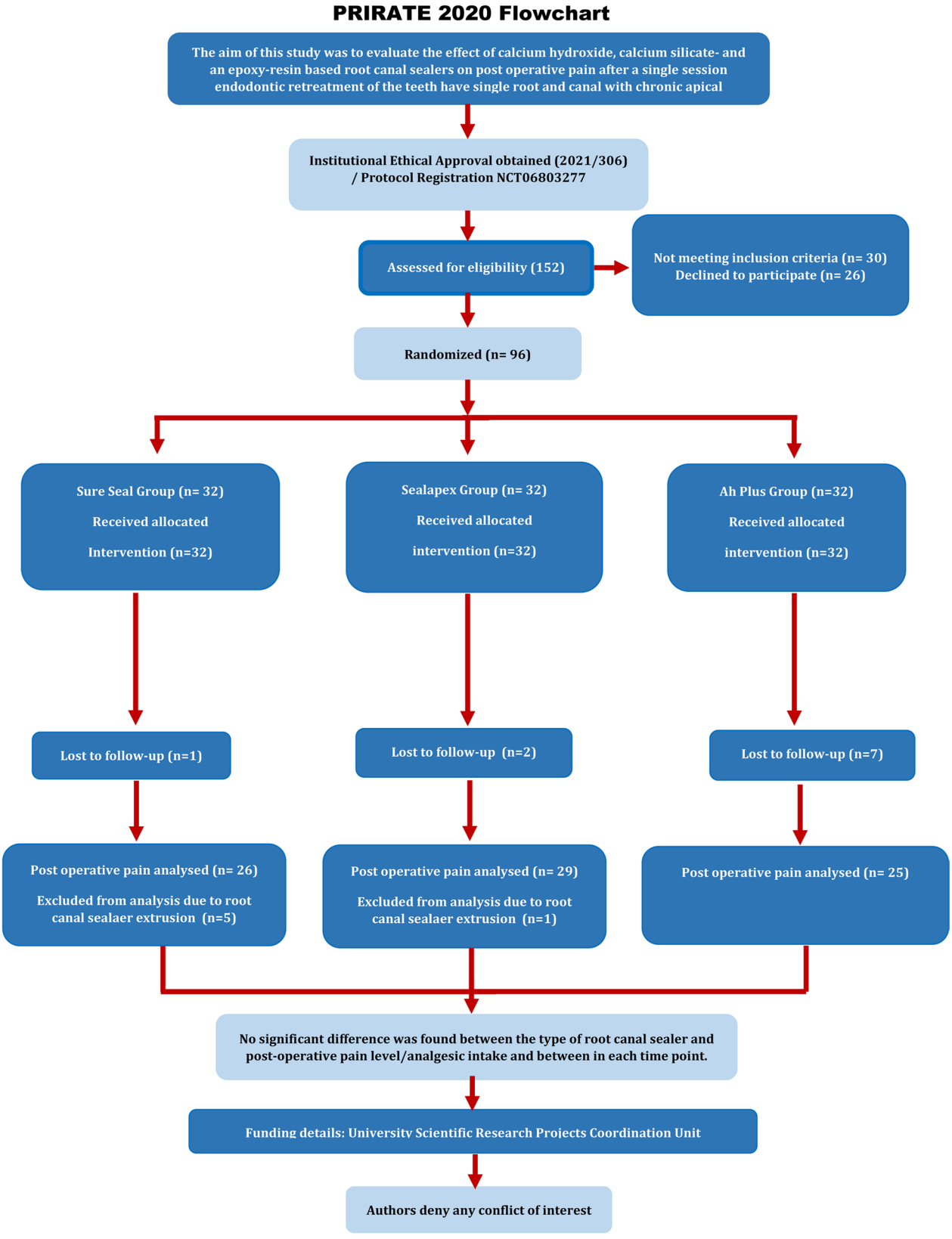


Fig. 1 Flow chart of participants along the study according to PRIRATE 2020

and no sinus track), single root and single canal, and chronic apical periodontitis and periapical index (PAI) scores of 2–4 were included in the study. The single canal and single root of the teeth included in this study were confirmed by periapical radiographs taken from different angles. Despite this, the two canalled teeth detected during endodontic retreatment were excluded from the study.

Exclusion criteria

Teeth with root resorption, crown damage, broken file and severe malocclusion, symptomatic teeth with PAI scores of 1 and 5, and immature teeth were excluded.

All ninety-six patients underwent a single session of endodontic retreatment. Ten patients were excluded from the study because of loss of follow-up. Then, six patients were excluded from the statistical analysis due to the extrusion of the root canal sealer.

Of the 80 patients included in the statistical analysis, 51 were female and 29 were male. The age range of patients was 18–68 years.

Treatment protocols

The randomization sequence was generated using a computerized random table number generator (www.random.org) by a dental assistant. The allocation ratio was 1:1. The participants were randomly allocated to one of the experimental groups. Due to the nature of the procedures, the operator (S.D.) was not blind to the procedures. The patients, however, were blinded and were not informed of their allocation.

Topical anesthesia (Xylocaine Spray, Sdörtalje, Sweden) was applied before local anesthesia. For local anesthesia of all teeth, 2 ml of 4% articaine (Ultracaine D-S forte, Aventis, Istanbul, Turkey) containing 1:100,000 epinephrine was used. After local anesthesia, a rubber dam was applied, and all teeth were cleaned with 10% povidone-iodine. In the presence of caries and old restorations, sterile diamond burs were used under water cooling to remove caries and old restoration, and then the endodontic access cavity was prepared.

After preparing the access cavity, the ProTaper universal retreatment (Dentsply Sirona, Ballaigus, Switzerland) system with D1(size 30/0.09 taper), D2(size25/0.08 taper), and D3 (size 20/0.07 taper) files was used at a speed of 500 rpm and a torque of 3 Ncm according to the manufacturer's instructions to remove root canal filling material. Firstly, the D1 file was used for the coronal region and the D2 file was used for the middle third region to remove the old root canal filling. After a glide path was created by #10 K-file, the WL was established by #10 or larger K-files and Propex pixi II apex locator (Dentsply Sirona) and confirmed on the x-ray. D3 file for the apical third was then used with light pressure until the working length (WL) was reached. After the root canal filling material was completely removed from the canals following the use of the D3(size 20/0.07 taper) file, the root canal of all teeth was reprepared again using Reciproc R25 and Reciproc R40 (Dentsply Sirona) at WL, respectively. The canals were irrigated using 3 mL sodium hypochlorite (NaOCl) during each file change. After completion of the root canal preparation, they were respectively irrigated with 10 mL of NaOCl and 5 mL of 17% EDTA using the medium tip size (25/0.04) of an EndoActivator device (Dentsply Sirona) and subsequently rinsed with 5 mL distilled water. All files were used according to the manufacturer's instructions.

Before obturating, the canals were dried using paper points. Patients were randomly divided into 3 groups according to the type of root canal sealer.

Sealapex root canal sealer (Kerr, Bioggio, Switzerland) and AH Plus root canal sealer were prepared according to the manufacturer's recommendations and sent into the canal with a lentulo at a speed of 300 rpm, 3 mm less than the WL. For Sure Seal bioceramic-based sealer (Sure Dent Corporation, Gyeonggi-do, South Korea) (SSBS), the intracanal tip of its was positioned at 2 mm coronal to the WL and then was withdrawn slowly coronally until the root canal was completely obturated. Then, 40.04 size tapered gutta-percha was coated with root canal sealers and placed in the canal at the WL. The gap into the canal, which was created by a size 25 finger spreader, was filled with a size 20 gutta-percha coated with root canal sealer until the spreader could not be inserted 2 mm further into the canal. The excess gutta-percha was removed by cutting with a hot hand tool and the excess sealer overflowing from the canal mouth was cleaned with cotton pellets [15].

All teeth were restored with composite resin (Charisma/Charisma Classic, Kulzer GmbH). All treatments were performed by a single operator. Patients were prescribed ibuprofen 400 mg (Brufen; Abbott Laboratory) and advised to use it when experiencing pain.

Postoperative pain evaluation

PP was assessed using a visual analog scale (VAS) at 6 h,12 h, 24 h, 48 h, 72 h, 4,5,6, and 7 days after retreatment. The VAS was a 100 mm horizontal scale with marks every 10 mm and no numbers except a 0 at the beginning of the scale and a 100 at the end. An investigator blinded to the study groups trained all participants to use the scale. The PP levels were classified as no pain (0–4 mm), mild pain (5–44 mm), moderate pain (45–74 mm), or severe pain (75–100 mm) [16].

PAI score evaluation

Two endodontists with at least 10 years of experience but not involved in the study were trained and calibrated

using radiographs of 100 teeth with chronic apical periodontitis outside of the study for PAI score evaluation before intervention. Where there was disagreement about the results, discussions were held until a consensus was reached. Kappa statistics were used to check for intra-observer reproducibility. The Kappa value of intra-observer agreement was 0.865.

Statistical analysis

Baseline demographic data and clinical features were analyzed by Pearson's chi-square test. The association between the PP categories and root canal sealers type was analyzed by chi-squared tests (Fisher's exact test). The correlation between the PP category and analgesic intake was evaluated by Spearman correlation analyses. Pearson's chi-square tests and the Goodman-Kruskal Gamma test were used to analyze the association between the clinical features of the participants and the PP category. All statistical analyses were performed using a software program (IBM SPSS Statistics, Version 22). For all analyses, the significance level was set at 0.05.

Results

Table 1 shows the baseline demographic data and clinical features of the participants included in the study. There was no significant difference in age, gender, tooth type, and periapical index score distributions between the groups ($P>0.05$). Table 2 shows the association between the PP category and root canal sealer type at each time point. No significant difference in PP levels between root canal sealers groups at any of the time intervals evaluated ($P>0.05$). Also, no significant difference was detected between analgesic intake and root canal sealers groups at any of the time intervals evaluated, too ($P>0.05$) (Table 3). Table 4 shows the evaluation of the correlation between PP category and analgesic intake, and there was a significant correlation between them ($P<0.05$). A strong positive correlation was observed at 48 h and 96 h when the correlation between PP and analgesic intake was evaluated regardless of the type of root canal sealer. Table 5 shows the analysis of the association between PP category and tooth region, gender, age, and PAI category. PP level was associated with age, gender, PAI score, and jaw type ($P<0.05$). The Goodman-Kruskal Gamma test was used to analyze the association between PAI scores and PP category (Table 5). There is a statistically significant ($P<0.001$) weak negative correlation (G=−0.248) between the PAI category and the PP category. The PP level decreases while the PAI score increases.

Table 1 Baseline demographic data and clinical features of participants included in the study

	Root Canal Sealer Types			Total	*P*
	Sealapex	Sure Seal	AH Plus		
Gender					0.954
Female	19	16	16	51	
Male	10	10	9	29	
Age					0.125
18–29	10	11	3	24	
30–59	10	10	15	35	
60+	9	5	7	21	
Jaw type					0.988
Upper	15	13	13	41	
Lower	14	13	12	39	
PAI Score					0.990
2	7	6	5	18	
3	10	8	9	27	
4	12	12	11	35	

Clinical baseline parameters for each study group. Chi-square *P* values are shown

Discussion

It is hypothesized that PP primarily results from irritation of periapical tissues due to the extrusion of debris, microorganisms, and chemical substances from the root canal system via the apical foramen. The degree of inflammation is directly proportional to the amount of these substances present [17]. Many parameters, such as WL, number of appointments, preparation technique, and type of root canal sealer, are associated with PP [18]. An endodontic sealer can be in close contact with periapical tissues during the root canal process through the apical foramen and lateral canals [19]. In the present study, there were no significant differences between used root canal sealers in terms of PP levels and analgesic intake after endodontic retreatment, so the null hypothesis was accepted.

All treatments in the current study were performed in a single visit to minimize the impact of intracanal medications on PP. Single-canalled teeth were also used in the current study to minimize the effects of various factors affecting the treatment of multi-rooted teeth. In addition, only asymptomatic patients were enrolled in the present study since preoperative pain is known to be a strong predictor of PP [20]. This study employed an electronic apex locator to determine the WL, thereby preventing over-instrumentation and overfilling. Intentional sealer extrusion was not performed in any of the cases. Although in 6 cases, unintentional extrusion occurred, these isolated events were excluded. The current study demonstrated that randomization ensured a similar demographic and relevant variable distribution among the root canal sealer groups. Despite these strengths, other potential variables related to the complex nature of pain should also be considered.

A study evaluating the effects of bioactive glass-based endodontic sealer, which is called bioceramic-based sealer too (Nishika BG) and epoxy resin-based root canal sealers (AH Plus) on PP in patients with primary

Table 2 Association between post-operative pain categories and types of root canal sealers at each time point

Time points after retreatment	*Pain Categories*	*Root Sealer Types*			**Total**	*P*
		Sure Seal	*AH plus*	*Sealapex*		
6 h	No pain	17 (33.3%)	13 (25.5%)	21(41.2%)	51(100%)	0.109*
	Mild Pain	8(36.4%)	6(27.3%)	8(36.4%)	22(100%)	
	Moderate pain	1 (20%)	4 (80%)	0 (0%)	5 (100%)	
	Severe pain	0(0%)	2(100%)	0 (0%)	2 (100%)	
12 h	No pain	17 (31.5%)	16(29.6%)	21 (38.9%)	54 (100%)	0.305*
	Mild Pain	6 (31.6%)	5 (26.3%)	8 (42.1%)	19(100%)	
	Moderate pain	3 (60%)	2 (40%)	0 (0%)	5 (100%)	
	Severe pain	0 (0%)	2(100%)	0 (0%)	2 (100%)	
24 h	No pain	18 (31.6%)	18 (31.6%)	21 (36.8%)	57 (100%)	0.909*
	Mild Pain	4 (33.3%)	3 (25%)	5 (41.7%)	12 (100%)	
	Moderate pain	3 (37.5%)	2 (25%)	3 (37.5%)	8 (100%)	
	Severe pain	1 (33.3%)	2 (67.7%)	0 (0%)	3 (100%)	
48 h	No pain	20 (32.3%)	19 (30.6%)	23 (37.1%)	62 (100%)	0.914*
	Mild Pain	4 (40%)	2 (20%)	4 (40%)	10 (100%)	
	Moderate pain	1 (%33.3)	1 (%33.3)	1 (%33.3)	3 (100%)	
	Severe pain	1 (20%)	3 (60%)	1 (20%)	5 (100%)	
3 days	No pain	22 (34.4%)	17 (26.6%)	25 (39.1%)	64 (100%)	0.658*
	Mild Pain	3 (27.3%)	5 (45.5%)	3 (27.3%)	11 (100%)	
	Moderate pain	0 (0%)	1 (0%)	0 (0%)	1 (100%)	
	Severe pain	1 (25%)	2 (50%)	1 (0%)	4 (100%)	
4 days	No pain	23 (33.3%)	19 (27.5%)	27 (39.1%)	69 (100%)	0.276*
	Mild Pain	2 (28.6%)	4 (57.1%)	1 (14.3%)	7 (100%)	
	Moderate pain	1 (33.3%)	2 (66.7%)	0 (0%)	3 (100%)	
	Severe pain	0 (0%)	0 (0%)	1 (100%)	1 (100%)	
5 days	No pain	23 (32.9%)	20 (28.6%)	27 (38.6%)	70 (100%)	0.364*
	Mild Pain	3 (30%)	5 (50%)	2 (20%)	10 (100%)	
	Moderate pain	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
	Severe pain	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
6 days	No pain	24 (32.4%)	22 (29.7%)	28 (37.8%)	74 (100%)	0.431*
	Mild Pain	2 (33.3%)	3 (50%)	1 (16.7%)	6 (100%)	
	Moderate pain	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
	Severe pain	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
7 days	No pain	24 (32.4%)	23 (31.1%)	27 (36.5%)	74 (100%)	1*
	Mild Pain	2 (33.3%)	2 (33.3%)	2 (33.3%)	6 (100%)	
	Moderate pain	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
	Severe pain	0 (0%)	0 (0%)	0 (0%)	0 (0%)	

* Fisher's Exact Test

endodontic lesions showed that Nishika BG caused significantly less pain than AH Plus [21]. That result is not consistent with the results of the current study. This may be because the contents of Sure Seal root canal sealer are different from Nishika BG root canal sealer. Sure Seal root canal sealer mainly contains calcium aluminate silicate, while Nishika BG root canal sealer contains calcium silicate glass. Another study evaluating the effect of bioactive glass-based, bioceramic-based, and epoxy resin-based root canal sealers on post-obturation pain showed that CSBS and bioactive glass-based sealers resulted in significantly lower levels of pain as compared to epoxy resin-based sealer (AH Plus) at 6 h and 24 h intervals [22]. The reason why the results of this study differ from the results of the current study may be the difference in the initial diagnoses of the patient groups used in the studies. In the current study, patient groups with asymptomatic chronic apical periodontitis were included, while in the other study, patient groups with symptomatic irreversible pulpitis and symptomatic apical periodontitis were included. Graunaite et al. evaluated the incidence of PP after root canal obturation with two root canal sealers (AH Plus and Totalfill) in patients with asymptomatic apical periodontitis and showed that both sealers caused similar post-operative pain [11]. Another study showed that three different root canal sealers (AH Plus, Endofill, and MTA Fillapex) used in teeth with asymptomatic necrosis and apical periodontitis on PP level caused

Table 3 The relationship between root canal sealer type and analgesic intakes at each time point

Time points after retreatment	Root Canal Sealer Type			P
	Number of analgesic intakes (n/N^{total}, %)			
	Sure Seal (N^{total}=26)	AH Plus (N^{total}=25)	Sealapex (N^{total}=29)	
6 h	2/26 (7.7%)	4/25 (16%)	1/29 (3.4%)	0.245*
12 h	4/26 (15.4%)	2/25 (8%)	1/29 (3.4%)	0.286*
24 h	4/26 (15.4%)	4/25 (16%)	3/29 (10.3%)	0.78*
48 h	2/26 (7.7%)	4/25 (16%)	4/29 (13.8%)	0.7*
3 days	1/26 (3.8%)	4/25 (16%)	2/29 (6.9%)	0.328*
4 days	1/26 (3.8%)	4/25 (16%)	1/29 (3.4%)	0.271*
5 days	1/26 (3.8%)	2/25 (8%)	0/29 (0%)	0.199*
6 days	1/26 (3.8%)	0/25 (0%)	0/29 (0%)	0.638*
7 days	0/26 (0%)	0/25 (0%)	0/29 (0%)	N/A

* Fisher's Exact Test

similar PP level and also similar analgesic intake requirements [23]. Büker et al. evaluated the effects of CSBS and CHBS on PP within mandibular first and second molar teeth with symptomatic apical periodontitis and revealed that using both sealers caused similar PP level and analgesic intake [24]. Another study evaluating different CSBSs on PP in teeth with different pulpal conditions showed that all CSBS used showed similar PP, but more analgesic use was required in cases where the pulp was vital [14]. Similarly, Nathani et al. found no differences in PP after root canal treatment using either AH plus or BioRoot™ RCS in cases diagnosed with asymptomatic and symptomatic apical periodontitis [25]. The results of the current study are similar to the results of all these studies. This may be attributed to the fact that the use of a root canal sealer used in root canal retreatment is usually limited within the root canal system, with minimal contact with periapical vital tissues. Thus, the effect of toxic materials, especially while the root canal sealers were set, was minimal.

In the literature, there is only one study examining the use of analgesics for PP with calcium hydroxide and bioceramic-based sealers. This study showed that the sealer type did not affect analgesic intake [24]. The results of this study are consistent with the results of the current study. In addition, one of the studies evaluating the use of analgesics for PP with bioceramic and resin-based sealers showed that a calcium silicate-based sealer was associated with less analgesic intake than a resin-based sealer [26], while other studies, consistent with the results of our study, showed that sealer type did not affect analgesic intake [27, 28].

A meta-analysis study on flare-ups after endodontic treatment revealed that strong pain with or without swelling could occur after the initiation or continuation of root canal treatment and within 48 h after the procedure [29]. In the current study, a strong positive correlation was observed at 48 h and 96 h when the correlation between PP and analgesic intake was evaluated regardless of the type of root canal sealer. The findings of the current study are consistent with the results of that study. On the other hand, when the correlation between the root canal sealers used within themselves, specifically between PP and analgesic intake, was evaluated, a strong positive correlation was not observed at any time point in Sure-seal root canal sealer. However, a strong positive correlation was observed at 48, 72, and 96 h. hours in Sealapex root canal sealer, at 24., 48.,72. and 96. hours in AH plus root canal sealer. One reason for these differences could be that PP may be linked to the initiation of reactive oxygen species (ROS) formation which is caused by the leaching of unpolymerized sealer components during the first 24 h because of Ah plus's delayed setting time and especially resin residues [30, 31] because PP in endodontics is known to be associated with the release of biochemical mediators such

Table 4 Evaluation of the correlation between post-operative pain categories and analgesic intake

Time points after retreatment	All root canal sealer (regardless of the root canal sealer type)		Sure Seal		AH Plus		Sealapex	
	Correlation coefficient (*r*)	*P* value	Correlation coefficient (*r*)	*P* value	Correlation coefficient (*r*)	*P* value	Correlation coefficient (*r*)	*P* value
6 h	0,447	0,000032	0,474	0,014	0,445	0,026	0,306	0,106
12 h	0,474	0,000009	0,625	0,001	0,419	0,037	0,306	0,106
24 h	0,699	0,000	0,672	0,000	0,756*	0,000012	0,673	0,000063
2 days	0,729*	0,000	0,536	0,005	0,819*	0,000	0,812*	0,000
3 days	0,654	0,000	0,447	0,022	0,735*	0,000029	0,706*	0,000019
4 days	0,728*	0,000	0,529	0,005	0,811*	0,000	0,720*	0,000011
5 days	0,522	0,000	0,554	0,003	0,590	0,002	N/A	N/A
6 days	–0,032	0,778	–0,058	0,779	N/A	N/A	N/A	N/A
7 days	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Statistical analysis was performed using Spearman correlation analysis

*A strong, statistically significant positive correlation exists between analgesic intake and the post-operative pain category

Table 5 Analysis of the association between post-operative pain category and tooth region, gender, age, and periapical index category

Pain Category	Teeth Region (% Within Pain Category)				
	Lower	**Upper**	**Total**		***P***
No pain	257[a] (44.7%)	318[b] (55.3%)	575 (100%)		0.0007*
Mild Pain	71[a] (68.9%)	32[b] (31.1%)	103 (100%)		
Moderate pain	15[a] (60.0%)	10[a] (40.0%)	25 (100%)		
Severe pain	8[a] (47.1%)	9[a] (52.9%)	17 (100%)		
Total	351 (48.8%)	369 (51.2%)	720 (100%)		
	Gender (% Within Pain Category)				
	Male	Female	Total		P
No pain	239[a] (41.6%)	336[b] (58.4%)	575 (100%)		0.000*
Mild Pain	17[a] (16.5%)	86[b] (83.5%)	103 (100%)		
Moderate pain	5[a] (20.0%)	20[a] (80.0%)	25 (100%)		
Severe pain	0[a] (0%)	17[b] (100%)	17 (100%)		
Total	261 (36.3%)	459 (63.7%)	720 (100%)		
	Age (% Within Pain Category)				
	18–29	30–59	60+	Total	P
No pain	187[a] (32.5%)	232[b] (40.3%)	156[a, b] (27.1%)	575 (100%)	0.000139*
Mild Pain	27[a] (26.2%)	50[a] (48.5%)	26[a] (25.2%)	103 (100%)	
Moderate pain	2[a] (8%)	18[b] (72.0%)	5[a, b] (20.0%)	25 (100%)	
Severe pain	0[a] (0%)	15[b] (88.2%)	2[a, b] (11.8%)	17 (100%)	
Total	216 (30%)	315 (43.8%)	189 (26.3%)	720 (100%)	
	PAI Category (% Within Pain Category)				
	PAI 2	PAI 3	PAI 4	Total	P
No pain	123 (21.4%) [a]	181 (31.5%) [a]	271 (47.1%) [b]	575 (100%)	0.000514**
Mild Pain	20 (19.4%) [a, b]	48 (46.6%) [b]	35 (34.0%) [a]	103 (100%)	
Moderate pain	11 (44%) [a]	11 (44%) [a]	3 (12.0%) [b]	25 (100%)	
Severe pain	8 (47.1%) [a]	3 (17.6%) [b]	6 (35.3%) [a, b]	17 (100%)	
Total	162 (22.5%)	243(33.8%)	315 (43.8%)	720 (100%)	

Different lowercase letters in the same line indicate statistically significant differences

*Pearson Chi-Square

**Goodman and Kruskal's Gamma

as ROS [32]. Another reason could be that an epoxy resin-based sealer has significantly higher pro-inflammatory cytokine levels (such as IL-6 and IL-8), which are associated with inflammatory responses after canal obturation, than the CSBS [33]. The reason why Sealapex showed a strong positive correlation compared to Sure Seal could be that It may have high solubility due to the presence of calcium hydroxide, which produces a porous matrix with high water absorption and calcium release [34].

Mild PP after root canal treatment is an expected outcome due to the nature of the procedure [35]. Treatment-related variables that may contribute to moderate and severe pain following endodontic retreatment should be carefully evaluated. Studies generally show that females are more sensitive to pain than males, although there are some inconsistencies [36]. Partially consistent with previous research [18], the current study revealed a statistically significant association between gender and mild and severe PP levels. Although no statistically significant difference was observed between gender and moderate PP level, females reported more pain than males. The increased severity of PP in women is likely due to physiological distinctions and fluctuations in hormone concentrations. As far as we know, there is one study evaluating the relationship between jaw type and PP. It showed that the PP levels were similar in both jaws [25]. The results of that study are partially consistent with the results of the current study. No statistically significant association was found between jaw type and moderate and severe PP categories in the current study. However, in the mild PP category, the pain level in the lower jaw was statistically significantly higher than in the upper jaw. The reason why the levels of pain, especially moderate and severe post-operative pain, were similar in both jaws could be that retreatment was performed by applying a standard treatment protocol to single-rooted and single-canal teeth in both jaw types. Many studies showed that there was no significant correlation between age and PP [24, 37]. However, in contrast to the results of these studies, the current study

showed that, statistically significantly, the incidence of moderate and severe pain was higher in patients aged 30–59 years compared to patients aged 18–29 years. Although there was no statistically significant difference between mild pain and age in terms of PP level, patients aged 30–59 years had more PP than patients aged 18–29 years. This may be due to a lack of experience and a more tolerant psychological attitude towards pain and discomfort in patients aged 18–29 years [38].

In the current study, the size of the periapical lesion was represented by PAI scores. As the PAI score increases, the size of the periapical lesion also increases. A previous study has shown that teeth with larger periapical lesion sizes (higher PAI score) exhibited lower PP after root canal treatment compared to teeth with smaller periapical lesion sizes (lower PAI score). The results of the current study are consistent with the findings of previous studies [39, 40]. A larger periapical lesion may be associated with a lower prevalence of PP because it acts as a buffer against pressure build-up by exudate during the inflammatory response to mechanical or chemical injury during root canal treatment.

The limitations of this study include the fact that pain is a subjective experience, the use of teeth that have a single root and a canal from the upper and lower jaws without jaw distinction, and patients' pain thresholds, psychological conditions, expectations, and individual responses may vary. Additionally, the use of analgesics by patients to reduce pain can make it difficult to determine the actual PP level. Furthermore, studies often lack strict control over medication use, and the current study was conducted with a limited number of patients.

Conclusion

Within the limitations of the current study, the root canal sealers used resulted in similar PP levels and analgesic usage. A strong positive correlation was observed at 48 h and 96 h when the correlation between post-operative pain and analgesic intake was evaluated, regardless of the type of root canal sealer. PP level was associated with age, gender, PAI score, and jaw type. Based on the results of the current study, the type of root canal sealer does not have an effect on PP after endodontic retreatment.

Abbreviations

PP	Postoperative pain
CHBSs	Calcium hydroxide-based sealers
CSBSs	Calcium silicate-based root canal sealers
Bis-GMA	Bisphenol A diglycidylether
PAI	Periapical index
WL	Working length
SSBS	Sure Seal bioceramic-based sealer
VAS	Visual analog scale
ROS	Reactive oxygen species

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

Salih Düzgün: Conceptualization, Investigation, Data curation, Funding acquisition, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft Haydar Albayrak: Formal analysis, Writing – original draft Hüseyin Sinan Topçuoğlu: Investigation, Writing– review & editing, Supervision. All authors reviewed the manuscript.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The ethics approval was obtained from the Erciyes University Medical Faculty Ethics Institution, with decision number 2021/306, and the study was registered under the protocol ID NCT06803277 (https://clinicaltrials.gov/) according to the CONSORT statement of the updated guidelines for reporting randomized clinical trials. Informed consent was taken from all participants. This Randomized Clinical Trial was conducted according to the guidelines of the Declaration of Helsinki.

Consent for publication

Not applicable

Competing interests

The authors declare no competing interests.

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