

AH Plus®
**SCIENTIFIC
MANUAL**

30 years of clinical success

AH Plus®
30 Years
Clinical Success

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1 AH Plus® and AH PlusJet®

Endodontic sealers play a crucial role in endodontic treatment, with primary clinical requirements including excellent biocompatibility and long-lasting sealing of the root canal. A leak-resistant seal is essential for preventing microbial infiltration and ensuring the success of the treatment. Achieving this seal depends on factors such as dimensional stability (shrinkage/expansion), low solubility, and ideally adhesion to both dentin and obturation materials. In addition, a sealer should demonstrate good radiopacity for easy identification during radiographic evaluation and be easy to apply [1].

Historically, root canal sealers were made from materials like zinc oxide-eugenol, calcium hydroxide, or medicinal substances such as formaldehyde or corticosteroids. However, the development of resin-based sealers marked a significant advancement in endodontics. The introduction of AH 26® (Dentsply DeTrey, Konstanz, Germany) in 1955, the first resin-based root canal sealer, marked a new era of sealing materials [2]. Over the decades, advancements continued, and in 1995, Dentsply launched AH Plus® (Dentsply DeTrey, Konstanz, Germany; **Figure 1**), a paste-paste epoxy resin-based sealer with improved proper-

ties, including enhanced dimensional stability, radiopacity, minimal shrinkage compensated by over time expansion, and without formaldehyde release [3]. In 2005, the product was further improved with the introduction of AH Plus Jet® (**Figure 1**), a user-friendly double-barrel syringe designed for easier application. AH Plus® is composed by an epoxide and an amine paste. The epoxide paste combines epoxide resins with radiopaque fillers and rheology modifiers, while the amine paste includes three types of amine components, radiopaque fillers, and rheology modifiers. Due to its specific composition, AH Plus® exhibits low solubility, self-adhesive

properties with adhesion to dentin, outstanding low leakage, and excellent sealing performance. The use of finely ground calcium tungstate and zirconium oxide with a filler content of approximately 76% facilitates superior radiopacity. AH Plus® builds on the long success of AH 26®, offering improved performance based on Dentsply's long-standing epoxy amine research. Today, AH Plus® has been described by many authors as the “gold standard” in root canal sealing materials, widely recognized for its long-term sealing performance, and serving as the benchmark for evaluating new sealers in both clinical and laboratory settings [2, 4].



Figure 1:

On the left, AH Plus® Root Canal Sealer tubes launched in 1995. On the right, AH Plus Jet® Root Canal Sealer syringes launched in 2005.

2 Key literature search

AH Plus® was launched in 1995 and the aim of this manual it is an evidence-based overview of the clinical success of AH Plus® over the 30 years since its introduction. More than 2500 articles have been retrieved after searching for AH Plus® in PubMed and EBSCO. From these, 30 articles were selected based on the inclusion criteria namely being a clinical study on AH Plus® written in English. No temporal restrictions were applied. In vitro and animal studies were excluded, as well as reviews, comments, letters to the editor, opinions, case reports, and off-label use of AH Plus®. Six additional studies were included after manual search in retrieved articles (**Figure 2**).

This scientific manual provides a synopsis of the key published research findings on AH Plus® and AH Plus Jet® focusing on its clinical and radiographic success in permanent mature and immature teeth and post-obturation pain assessment. Each summary is based on facts retrieved from the original research article.

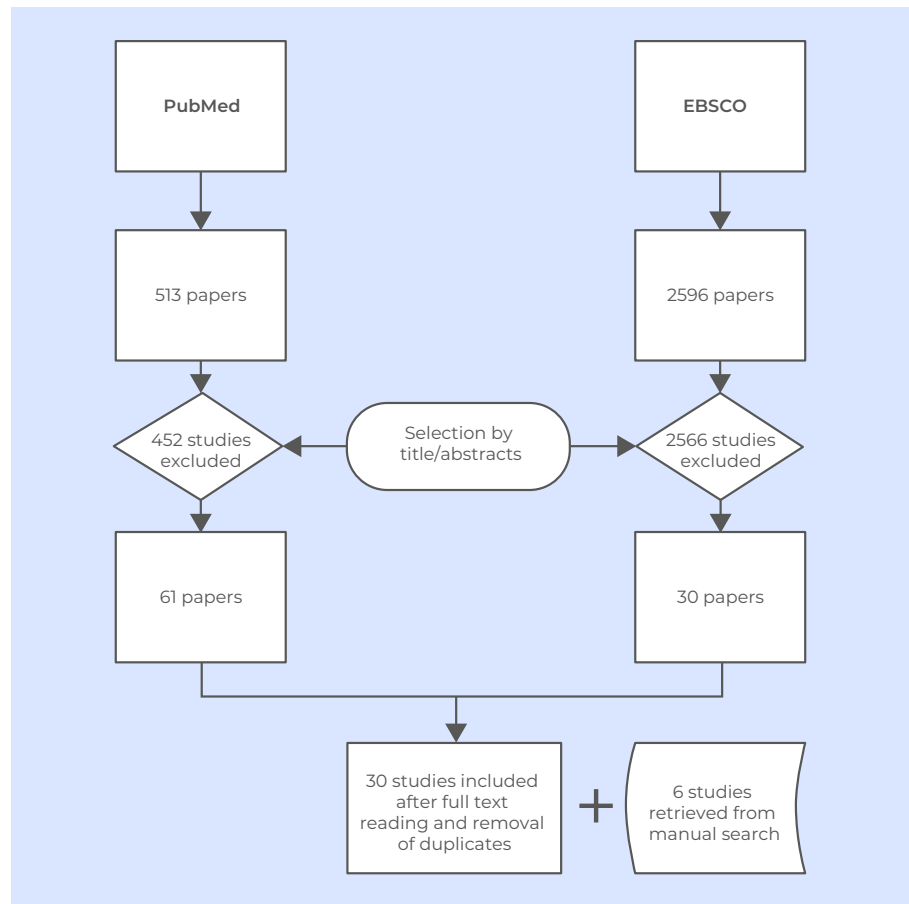


Figure 2:
Search workflow.

3 General summary of the included studies

A total of 36 clinical studies were included in this manual. The characteristics of the included studies are summarized on **Figure 3**.

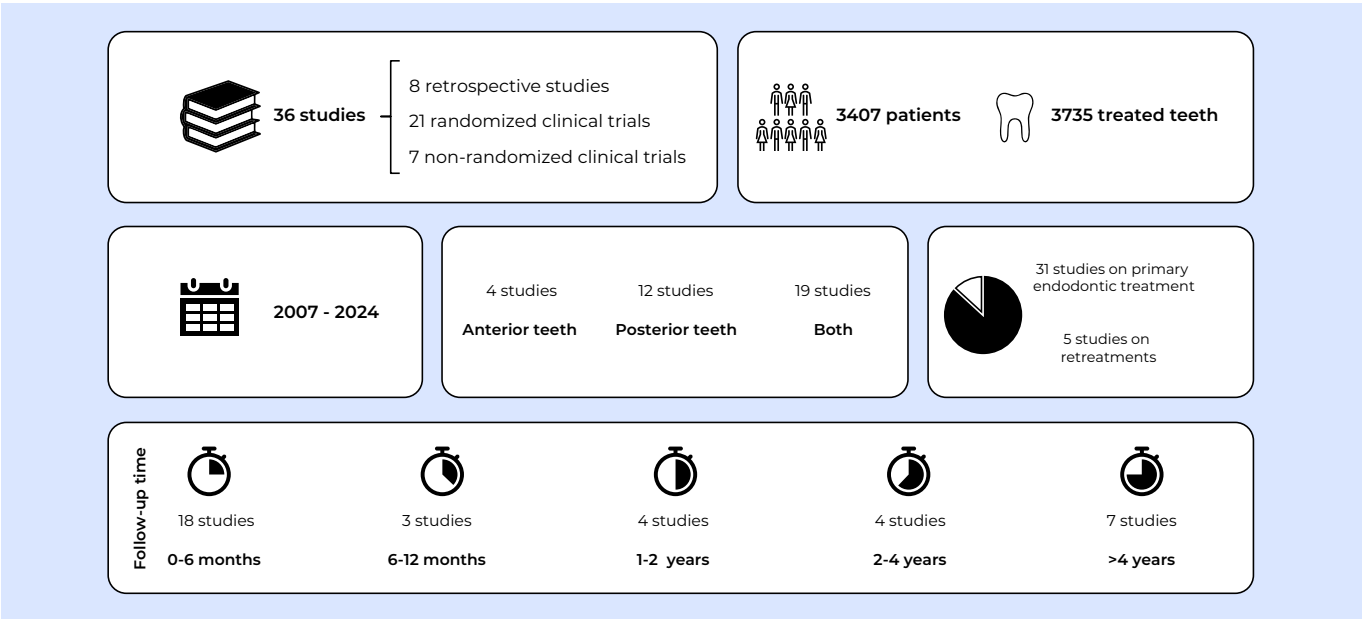


Figure 3:
Summary of the characteristics of the included studies.

The most used file systems in the selected studies were Protaper Next® (Dentsply Maillefer, Ballaigues, Switzerland) (N=6), followed by Protaper® Universal (Dentsply Maillefer, Ballaigues, Switzerland) (N=5),

and WaveOne® Gold (Dentsply Maillefer, Ballaigues, Switzerland) (N=4). Several sealers were tested against AH Plus®, some of which being EndoSequence BC Sealer (Brasseler, Savannah, GA, USA) (N=4), TotalFill

BC (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) (N=3), EndoSeal MTA (Maruchi, Wonju, South Korea) (N=3), and RealSeal (SybronEndo, Orange, CA) (N=3).

4 Main outcomes from the selected studies

The selected studies are divided by main outcomes (post-obturation pain assessment or clinical and/or radiographic success) and subdivided by their obturation technique (cold lateral condensation, carrier-based obturation, warm obturation techniques (without carrier), and single cone obturation).

1. Pain assessment

Post-obturation pain after root canal treatments is an expectable and frequent observation, ranging from mild to severe, and can persist from a day to several weeks, in which it may affect patient satisfaction (5). In this manual, a total of 22 studies aimed at comparing the incidence and severity of (mostly) short-term post-obturation pain after the treatment with different sealers, including AH Plus®. Regarding the methods to measure post obturation pain, scales such as Visual Analog Scale (VAS) or Numerical Rating Scale (NRS) were used. A summary of the methods and main results of each included study can be seen below.

a. Cold lateral condensation

Study 1

Title: Postoperative pain of single-visit endodontic treatment with gutta-percha versus MTA filling: a randomized superiority trial.

Authors: Khabiri M, Kamgar S, Iranmanesh P, Khademi A, Torabinejad M.

Published in: BMC Oral Health. 2023 Dec 19;23(1):1026.

Methods: This study aimed to compare postoperative pain levels following root canal treatment using gutta-percha (GP) with sealer (AH Plus®) versus mineral trioxide aggregate (ProRoot® MTA, Dentsply Tulsa Dental, Tulsa, OK, USA) as filling materials in teeth with asymptomatic apical periodontitis. The study included 94 single-canal maxillary or mandibular premolars with asymptomatic necrotic pulp (46 treated with AH Plus® and 48 with ProRoot® MTA). Teeth were shaped using Protaper® Universal files (Dentsply Maillefer, Ballaigues, Switzerland), irrigation with 2.5% NaOCl and saline solution, and cold lateral condensation as obturation technique. In the ProRoot® MTA group, an MTA apical filling was followed by a coronal GP and sealer filling. Pain was assessed 6, 12, 24,

and 72 hours after treatment using a 10-point Visual Analog Scale (VAS).

Results: The peak of pain intensity occurred 6 hours after treatment and decreased significantly over time for both groups. However, VAS scores were consistently lower in the MTA group compared to the GP group at all time points ($p < 0.05$). Additionally, female patients reported higher pain scores at 6 and 12 hours ($p < 0.05$), but not at later time points. Three participants experienced swelling (2 in the MTA group and 1 in the AH Plus® group) and one case of discoloration in the MTA group [6].

Study 2

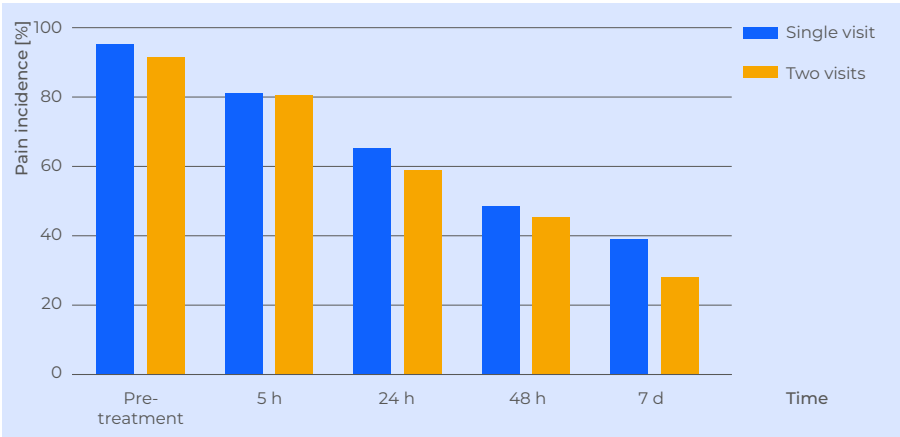
Title: Predictive models of pain following root canal treatment: a prospective clinical study.
Authors: Arias A, de la Macorra JC, Hidalgo JJ, Azabal M.
Published in: Int Endod J. 2013 Aug;46(8):784-93.

Methods: This study aimed to determine factors influencing the incidence, intensity, duration, and triggers of post-endodontic pain after root canal treatment sealed with AH Plus®. A total of 316 valid questionnaires were returned and used to adjust the logistic regression models, while 58 valid responses were used to assess the validity of the models.

Results: About 47.3% of patients (177 cases) reported post-endodontic pain. Around 69.5% of patients experienced pain for 1–2 days, while 30.5% had pain lasting 3–9 days. Pain was triggered by occlusal pressure in 36.2% of cases, spontaneously in 49.2%, and by both in 14.7%. From

the participants who experienced pain, 43.5% had mild pain, 45.8% moderate pain, and 9.6% intense pain. Lower incidence of pain was linked to non-molar teeth ($p=0.003$), the absence of periapical radiolucency ($p=0.003$), no previous pain history ($p=0.006$), no emergency treatment ($p=0.045$), and no occlusal contact ($p<0.0001$). Higher probability of moderate/severe pain was observed with increasing age ($p=0.09$) and in mandibular teeth ($p=0.045$). Males were less likely to have prolonged pain ($p=0.007$). The study found that the incidence of post-endodontic pain was influenced by tooth type, periapical condition, previous pain history, and occlusal contact [7].

Figure 4:
Pain incidence over time in the study by Wang, Xu [8]. No statistically significant differences were observed between one or two visits over time (Chi-square test).



Study 3

Title: Comparison of post-obturation pain experience following one-visit and two-visit root canal treatment on teeth with vital pulps: a randomized controlled trial.

Authors: Wang C, Xu P, Ren L, Dong G, Ye L.

Published in: Int Endod J. 2010 Aug;43(8):692-7.

Methods: This study aimed to compare the incidence and intensity of post-obturation pain following one-visit versus two-visit root canal treatments (RCT) in anterior teeth with vital pulps and a single root and canal. A total of 89 patients were included, with 43 receiving single-visit RCT and 46 receiving two-visit RCT. All the teeth treated were vital, with no calcified canals, and had fully formed foramina, confirmed by preoperative radiographs. The root canal procedures were performed using Protaper® Universal files (Dentsply Maillefer, Ballaigues, Switzerland) and hand files, with 2.5% sodium hypochlorite for irrigation, lateral condensation for obturation, and AH Plus® sealer. Calcium hydroxide paste was used as an intracanal medicament when required. Post-treatment pain was assessed at 6, 24, 48 hours, and 1 week using the modified verbal descriptor scale (VDS), where pain severity ranged from 0 to 10 (corresponding to the categories “no pain” to “severe pain”).

Results: The results showed no significant difference in the incidence or intensity of post-obturation pain between the one-visit and two-visit groups at any of the time intervals. Twenty-four hours after the treatment, 65.1% of patients from the single-visit group and 58.7% from the two-visit group experienced pain and this percentage decreased over time (**Figure 4**). Both groups reported similar percentages of patients experiencing no pain or only slight pain 24 hours after obturation (**Table 1**). A small percentage of patients in both groups reported moderate to strong pain, but the differences between groups were not statistically significant. In conclusion, the study found no significant difference in post-obturation pain between one-visit and two-visit root canal treatments in vital anterior teeth. Most patients in both groups experienced either no pain or only mild discomfort following the procedure [8].

4 Main outcomes from the selected studies

Study 4

Title: Comparative evaluation of postoperative pain and periapical healing after root canal treatment using three different base endodontic sealers - A randomized control clinical trial.

Authors: Khandelwal A, Jose J, Teja KV, Palanivelu A.

Published in: J Clin Exp Dent. 2022 Feb 1;14(2):e144-e152.

Methods: This study evaluated postoperative pain and periapical healing after root canal treatment using three different endodontic sealers: Tubli-Seal (SybronEndo, Romulus, MI, USA), AH Plus®, and BioRoot RCS (Septodont, USA), with 18 maxillary anterior teeth per group. The participants were diagnosed with necrotic pulp and chronic apical periodontitis. Treatment was performed using Protaper Gold® (Dentsply Maillefer, Ballaigues, Switzerland) under irrigation with 3% sodium hypochlorite and 17% EDTA, and obturated using cold lateral condensation. Post-operative pain was assessed at 24 hours, 48 hours, 72 hours, and 7 days using a Visual Analog Scale (VAS).

Periapical healing was evaluated at baseline, and at 1-, 3-, and 6-months post-treatment by measuring the size of the apical lesion.

Results: In terms of pain, there were no significant differences among the groups, apart from Tubli-Seal and BioRoot RCS at 24 h (p=0.001). For the BioRoot RCS group compared to the other sealers, sealer extrusion was linked to significantly less postoperative pain at both 24 hours and 48 hours (p=0.028 and p=0.040, respectively) (Table 1). In sum, all sealers reduced postoperative pain 3 and 6 months after treatment and sealer extrusion was associated with less pain with BioRoot RCS [9].

Table 1:
Pain intensity levels over time for AH Plus®, Tubli-Seal, and BioRoot RCS.

Time	AH Plus®	Tubli-Seal	BioRoot RCS
24 h	11.57±11.18	17.94±11.35*	4.73±7.72*
48 h	1.57±3.74	5.26±9.04	1.57 ± 3.74
72 h	0	2.63±7.33	0
7 d	0	0	0

*p=0.001 between Tubli-Seal and BioRoot RCS (Mann Whitney U test).



Take home message

Similar to the other tested sealers, mild to moderate pain after treatment was observed in teeth treated with AH Plus® in the evaluated cold lateral condensation studies, which resolved mainly after the first 72 hours. Post-endodontic pain was often associated with other factors, such as periapical conditions before the treatment, but not the number of visits. In the majority of studies, there was no difference in pain intensity when AH Plus® was compared with bioceramic and zinc oxide eugenol sealers.

b. Carrier-based obturation

Study 5

Title: Post-obturation pain following the use of carrier-based system with AH Plus® or iRoot SP sealers: a randomized controlled clinical trial

Authors: Atav Ates A, Dumani A, Yoldas O, Unal I.

Published in: Clin Oral Investig. 2019 Jul;23(7):3053-3061.

Methods: This study aimed to compare the incidence and intensity of postoperative pain, as well as root canal filling extrusion, using a carrier-based obturation system with two different sealers (AH Plus® and iRoot SP (Innovative BioCeramix Inc., Vancouver, Canada)) in vital and devitalized permanent mandibular premolars or molars (N=39 per group). The treatments were performed in a single visit. Treatments were done using One Shape file system (Micro-Mega, Besançon, France) and irrigation with 2.5% sodium hypochlorite and 17% EDTA. Obturation was performed with a carrier-based system (Herofill™ Soft-Core obturators (Micro-Mega, Besançon, France)). Pain was evaluated using a 10 cm Visual Analog Scale (VAS) at 6, 12, 24, and 72 hours post-obturation. Extrusion of the filling was also recorded radiographically.

Results: Results showed that 68% of patients with AH Plus® and 59% with iRoot SP experienced pain in the first 6 hours, with pain intensity decreasing significantly over time ($p<0.001$). Twelve hours after, patients with premolars filled with iRoot SP reported less pain than those with AH Plus® ($p=0.042$), although no significant differences in pain intensity were noted for molar teeth. Analgesic intake was higher in the AH Plus® group during the first 12 hours ($p=0.014$), and patients with vital teeth treated with AH Plus® had a 2.5-fold higher risk of requiring analgesics compared to those using iRoot SP. Extrusion rates were highest in the AH Plus® (devitalized group) but did not differ significantly among the groups. Overall, the type of sealer did not have a significant impact on pain levels post-treatment [10].



Take home message

A reduction of post-treatment pain within the first 48 hours as observed with AH Plus®, when used for carrier-based obturation.

c. Warm obturation (without carrier)

Study 6

Title: Comparison of Postobturation Pain Experience after Apical Extrusion of Calcium Silicate- and Resin-Based Root Canal Sealers.
Authors: Drumond JPSC, Maeda W, Nascimento WM, Campos DL, Prado MC, de-Jesus-Soares A, Frozoni M.
Published in: J Endod. 2021 Aug;47(8):1278-1284.

Methods: This study aimed to compare postoperative pain intensity following unintentional apical extrusion of calcium silicate-based root canal sealers (EndoSequence BC Sealer (Brasseler, Savannah, GA, USA) and Bio-C Sealer (Angelus, Londrina, PR, Brazil)) with a resin-based sealer (AH Plus®). The research involved 110 patients who required nonsurgical root canal treatment for molar teeth with asymptomatic irreversible pulpitis and with 1-2mm extrusion of sealers beyond the apical foramen. Instrumentation was performed using WaveOne® Gold files (Dentsply Maillefer, Ballaigues, Switzerland), followed by irrigation with 2% chlorhexidine, saline solution, and 17% EDTA, and obturation with warm vertical compaction. Post-obturation pain was measured using a numeric rating scale 6, 12, 24, 48 hours, and one week after treatment.

Results: The extrusion rate was similar for all sealers (approximately 12%). The study found no significant difference in pain intensity among the different sealers at any time point. However, pain levels decreased significantly in the AH Plus® and Bio-C Sealer groups after 12 hours, while the EndoSequence BC Sealer did not show significant differences up to a week post-obturation (**Table 2**). Overall, unintentional apical extrusion of both types of sealers resulted in similar low-intensity postoperative pain, suggesting that both calcium silicate-based and resin-based sealers have comparable consequences for this outcome [11].

Table 2:
Pain intensity per time point for the three different sealers.

Time	AH Plus®	EndoSequence BC sealer	ISP (D)	p-value ¹
6 h	0.77±1.2	1.23±1.6	1.08±1.8	0.8
12 h	0.62±1.1	0.77±1.2	1.00±1.6	0.8
24 h	0.15±0.4	0.54±1.3	0.08±0.3	NA
48 h	0.23±0.8	0.69±1.7	0	0.3
7 d	0	0.15±0.4	0	0.1

¹Mixed model ANOVA. NA -Not available.

Study 7

Title: Comparing the incidence of postoperative pain after root canal filling with warm vertical obturation with resin-based sealer and sealer-based obturation with calcium silicate-based sealer: a prospective clinical trial

Authors: Yu YH, Kushnir L, Kohli M, Karabucak B.

Published in: Clin Oral Investig. 2021 Aug;25(8):5033-5042.

Methods: This study aimed to compare postoperative pain following single-visit, non-surgical root canal treatment for teeth with irreversible pulpitis (either symptomatic or asymptomatic), using two different sealers: AH Plus® and EndoSequence BC Sealer (Brasseler, Savannah, GA, USA). Forty-one teeth with irreversible pulpitis (either symptomatic or asymptomatic) were treated with AH Plus® and 51 with EndoSequence BC Sealer. The treatments were performed using rotary nickel-titanium instruments under 4% sodium hypochlorite irrigation. Two obturation techniques were used, namely warm vertical compaction (AH Plus®) and single cone (EndoSequence BC sealer). Patients were asked to rate their postoperative pain using a numeric rating scale (NRS) and the Wong-Baker facial grimace scale at 4-, 24-, and 48-hours post-treatment. Analgesic intake was also recorded.

Results: Results showed that pain levels decreased over time for both groups, with no significant differences in postoperative pain between the two sealing techniques at any time point. However, the AH Plus® group had more cases of sealer extrusion and patients with sealer extrusion reported higher pain levels. Factors such as age, gender, preoperative pain, and sealer extrusion were found to influence postoperative pain, while periapical symptoms and dentist clinical experience did not. In conclusion, the technique of obturation did not significantly affect postoperative pain levels and for teeth with symptomatic irreversible pulpitis the pain decreased after 48h regardless of the obturation technique [12].

Study 8

Title: Effect of Resin-based and Bio-ceramic Root Canal Sealers on Post-operative Pain: A Split-mouth Randomized Controlled Trial

Authors: Graunaite I, Skucaite N, Lodiene G, Agentiene I, Machiulskiene V.

Published in: J Endod. 2018 May;44(5):689-693.

Methods: This study aimed to compare the effects of resin-based (AH Plus®) and bioceramic (TotalFill BC sealer (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland)) root canal sealers on postoperative pain in patients with asymptomatic apical periodontitis. Fifty-seven single-rooted teeth requiring retreatment were included. Only teeth with a periapical index (PAI) score of 2 to 4 (indicating small to moderate lesions) were considered. The retreatments involved using Protaper® Universal files (Dentsply Maillefer, Ballaigues, Switzerland) and 2% sodium hypochlorite for irrigation. Postoperative pain was assessed using a visual analog scale (VAS) at intervals of 24 hours, 48 hours, 72 hours, and 7 days after treatment.

Results: There was no incidence of pain after 48 hours, with VAS scores of 80 for AH Plus® and 70 for Total-Fill BC sealer 24h after retreatment. The study found no statistically significant difference in pain levels between the two groups at any time point. However, a higher likelihood of pain occurrence was noted in lower premolars compared to upper front teeth. Overall, postoperative pain was low, affecting about 35% of participants, with both sealers performing similarly in terms of pain occurrence and intensity [13].

Study 9

Title: Comparative evaluation of pain, tenderness and swelling followed by radiographic evaluation of periapical changes at various intervals of time following single and multiple visit endodontic therapy: an in vivo study.

Authors: Prashanth MB, Tavane PN, Abraham S, Chacko L.

Published in: J Contemp Dent Pract. 2011 May 1;12(3):187-91.

Methods: This study aimed to assess the incidence and severity of pain, swelling, tenderness, and periapical healing following single-visit and multiple-visit endodontic therapy, in different categories of cases. A total of 32 patients were included, divided into four groups of 8 each. Group I consisted of single-visit endodontic therapy for vital teeth without periapical rarefaction; Group II involved single-visit therapy for asymptomatic pulpless teeth with periapical rarefaction; Group III involved multiple-visit therapy for vital teeth without periapical rarefaction; and Group IV included multiple-visit therapy for asymptomatic pulpless teeth with periapical rarefaction. All teeth treated were single or two-rooted anterior and premolar teeth with straight canals. The root canal treatments were performed using Protaper® Universal instruments (Dentsply Maillefer, Ballaigues, Switzerland), with sodium hypochlorite and EDTA as irrigants, and AH Plus® sealer with vertical compaction for obturation. The patients were evaluated clinically and radiographically at 48 hours, 1, 4, and 6 weeks.

Results: The results showed that mild pain was reported by 12.5% of patients in Groups I, II, and IV, but none of the patients in Group III reported any pain. None of the patients in any group experienced pain after 1, 4, or 6 weeks. There were no significant differences in post-operative pain, tenderness, or swelling between the single-visit and multiple-visit treatment groups. In conclusion, there was no significant difference in the incidence of pain, swelling, tenderness, or radiographic outcomes between single-visit and multiple-visit endodontic therapy, regardless of whether the teeth were vital or nonvital [14].

4 Main outcomes from the selected studies

Study 10

Title: The efficacy of 3 root canal sealers combined with warm gutta-percha vertical compression technique in the treatment of dental pulp disease.

Authors: Li W, Ju B, Cheng G, Lv Z.

Published in: *Medicine* (Baltimore). 2024 Jun 14;103(24):e38414.

Methods: This study evaluated the efficacy of three root canal sealants – AH Plus®, GuttaFlow (Coltene Whaledent GmbH and Co KG, Langenau, Switzerland), and iRoot SP (Innovative BioCeramix Inc., Vancouver, Canada) – when combined with the warm gutta-percha vertical compaction technique in treating dental pulp disease. Posterior teeth with deep caries, acute or chronic pulpitis, and periapical lesions were divided into three groups (60 per sealer). The root canal treatment was performed using coronal descending method teeth were obturate

using continuous wave compaction. This study assessed postoperative pain, quality of root canal filling, filling time, inflammatory markers (IL-6 and TNF- α), and overall treatment efficacy after 6 months.

Results: After 6 months, GuttaFlow and iRoot SP showed lower pain rates compared to AH Plus® (16.67% for AH Plus®, 5% for GuttaFlow, and 3.33% for iRoot). The study concluded that iRoot SP and GuttaFlow were more effective than AH Plus® in minimizing postoperative pain and inflammation [15].

Study 11

Title: Clinical Efficacy of Sealer-based Obturation Using Calcium Silicate Sealers: A Randomized Clinical Trial

Authors: Kim JH, Cho SY, Choi Y, Kim DH, Shin SJ, Jung IY.

Published in: *J Endod*. 2022 Feb;48(2):144-151.

Methods: This study compared the clinical efficacy of a sealer-based obturation technique (Endoseal TCS (Maruchi, Wonju, South Korea), SBO) with calcium silicate sealers to a continuous wave of condensation technique using a resin-based sealer (AH Plus®, CWC). Thirty-nine teeth were treated with AH Plus® and thirty-five with Endoseal. Treatments required at least two visits, and 2.5% sodium hypochlorite was used during irrigation. Postoperative pain was assessed using a numerical rating scale (NRS) at 4, 24, and 48 hours. Patients were recalled at least 6 months later for clinical and radiographical evaluation. The cli-

nical and radiographical outcomes were evaluated based on loose criteria (“Healed” and “Healing” categories were classified as success and the “Diseased” category was classified as failure) and strict criteria (only “Healed” was regarded as success).

Results: A significant majority (89.2%) reported no or mild pain post-treatment, with no significant differences between groups. Sealer extrusion and longer filling lengths were more frequent in the CWC group, although statistical significance was not attained [16].

Study 12

Title: Comparison of the Effects of a Bioceramic and Conventional Resin-Based Sealers on Postoperative Pain after Nonsurgical Root Canal Treatment: A Randomized Controlled Clinical Study.

Authors: Shim K, Jang YE, Kim Y.

Published in: Materials (Basel). 2021 May 19;14(10):2661.

Methods: This study compared the effects of a bioceramic sealer (Endoseal MTA, (Maruchi, Wonju, South Korea)) and a resin-based sealer (AH Plus®) on postoperative pain in patients undergoing root canal treatment. A total of 67 teeth were included, 32 in the AH Plus® group and 35 in the Endoseal MTA group. Treatment involved multiple visits, using Protaper Next® instruments (Dentsply Maillefer, Ballaigues, Switzerland) with sodium hypochlorite and EDTA for irrigation. Postoperative pain was assessed daily for a week using a visual analog scale (VAS).

Results: Results indicated no significant differences in pain incidence or intensity between the two sealers. VAS scores generally decreased over time for both groups, and none of the preoperative factors significantly affected pain levels. Teeth treated with Endoseal MTA required less obturation time compared to those treated with AH Plus®. In conclusion, both sealers had similar effects on postoperative pain, with Endoseal MTA leading to shorter obturation times in molars [17].



Take home message

When used for warm obturation techniques, AH Plus® was linked to mild levels of postoperative pain that decreased after 48h. Factors such as preoperative pain were associated with pain, whereas the number of visits did not seem to impact this outcome. Sealer extrusion and its association with pain presented contradictory results. There was no difference in pain intensity in comparison with bioceramic sealers in most studies.

d. Single cone obturation

Study 13

Title: Effect of Endodontic Sealer in Young Molars Treated by Undergraduate Students - A Randomized Clinical Trial

Authors: Cunha SA, Soares CJ, Rosatto CMP, Vieira JVSM, Pereira RADS, Soares PBF, Leles CR, Moura CCG.

Published in: Braz Dent J. 2020 Nov-Dec;31(6):589-597.

Methods: This study assessed the impact of two endodontic sealers – Sealer 26 (Dentsply Sirona, York, Pennsylvania, USA) and AH Plus® – on pain incidence and apical repair

in immature permanent molars after endodontic treatment. Sixty-nine molars with extensive caries and diagnosis of symptomatic irreversible pulpitis or necrosis were included. Treatment involved 2 to 4 visits, instrumenting with Protaper Next® files (Dentsply Maillefer, Ballaigues, Switzerland), and irrigating with 2.5% sodium hypochlorite and 17% EDTA. Obturation was done by single cone technique with both sealers. In cases the canal was more oval, some accessory cones were used. The follow-up moments were 12 and 24 months after treatment, when two blinded operators assessed the apical repair (absence of radiolucency) and postoperative pain.

Results: Overall, only 3.2% of patients reported pain at one year, increasing to 10% at two years. Periapical conditions and unsatisfactory pulpectomy prior to endo treatment were not predictors of the occurrence of pain in both periods [18].

Study 14

Title: Pilot Evaluation of Sealer-Based Root Canal Obturation Using Epoxy-Resin-Based and Calcium-Silicate-Based Sealers: A Randomized Clinical Trial.

Authors: Song M, Park MG, Kwak SW, Kim RH, Ha JH, Kim HC.

Published in: Materials (Basel). 2022 Jul 25;15(15):5146.

Methods: This study evaluated the short-term clinical effectiveness of sealer-based root canal obturation by comparing two calcium-silicate-based sealers (CeraSeal (Meta Biomed, Cheongju, South Korea) and EndoSeal TCS (Maruchi, Wonju, South Korea)) and two epoxy-

xy-resin-based sealers (AH Plus® and Adseal (Meta Biomed, Cheongju, South Korea)). It included 71 teeth with asymptomatic irreversible pulpitis or pulp necrosis, which were instrumented with Protaper Next® (Dentsply Maillefer, Ballaigues, Switzerland) and irrigated with 2.5% sodium hypochlorite and EDTA. For the obturation, sealers were introduced with a premixed syringe (CeraSeal and EndoSeal TCS) or with a master cone (AH Plus® and Adseal). Then, a master cone was placed to working length. Outcomes were assessed through clinical evaluations, radiographic assessments, and pain severity using visual analog scales (VAS) at 7 days, 1 month, and 3 months post-treatment.

Results: Results showed no significant differences among the sealers regarding voids, sealer extrusion, or postoperative pain levels. Pain scores were consistently low across all groups, with AH Plus® showing a slight increase in VAS scores from one week to one month after treatment. Overall, the study found that on short term all sealers performed similarly regarding postoperative pain and effectiveness [19].

Study 15

Title: The effect of two different root canal sealers on treatment outcome and post-obturation pain in single-visit root canal treatment: A prospective randomized clinical trial
Authors: Coşar M, Kandemir Demir-ci G, Çalışkan MK.
Published in: Int Endod J. 2023 Mar;56(3):318-330

Methods: This study compared the incidence and intensity of post-operative pain, as well as treatment outcomes, between two types of root canal sealers: mineral trioxide aggregate (MTA)-based bioceramic sealer (MTA Fillapex (Angelus, Londrina, Brazil)) and epoxy resin-ba-

sed sealer (AH Plus®). In this study, 38 mandibular molars with symptomatic irreversible pulpitis were treated with MTA and 37 with AH Plus®. Treatment was performed with WaveOne® Gold file system (Dentsply Maillefer, Ballaigues, Switzerland) and irrigation included 2.5% sodium hypochlorite and 17% EDTA. Obturation was done using a single cone corresponding in size and taper with the final file and if necessary, accessory cones were used. Post-operative pain was assessed using a Numerical Rating Scale (NRS) 6, 12, 24, 48, 72 hours, 4, 5-, 6-, 7- and 30-days post-treatment. Clinical and radiographic evaluations were conducted at 1- and 2-years post-treatment.

Results: Pain levels peaked at 6 hours post-treatment (74% for MTA, 73% for AH Plus®) but significantly decreased over time. By the second day, pain was significantly reduced in the MTA group, while the AH Plus® group saw significant reduction by the third day. At the 30-day follow-up, no pain was reported in the AH Plus® group, while 5% of the MTA group reported pain (Table 3). Overall, both sealers demonstrated similar postoperative pain incidence and intensity [20].

Table 3:
Mean pain intensity levels for treatment with AH Plus® or MTA Fillapex.

Time	AH Plus®	MTA Fillapex	p-value ¹
6 h	1.92	1.61	>0.05
12 h	1.55	1.62	>0.05
24 h	0.97	1.18	>0.05
48 h	0.54	0.79	>0.05
72 h	0.3	0.5	>0.05
7 d	0	0.05	>0.05
30 d	0	0.03	>0.05

¹Mann–Whitney U test

Study 16

Title: Postoperative pain after root canal filling with different endodontic sealers: a randomized clinical trial
Authors: Ferreira NS, Gollo EKF, Boscato N, Arias A, Silva EJNLD
Published in: Braz Oral Res. 2020;34:e069.

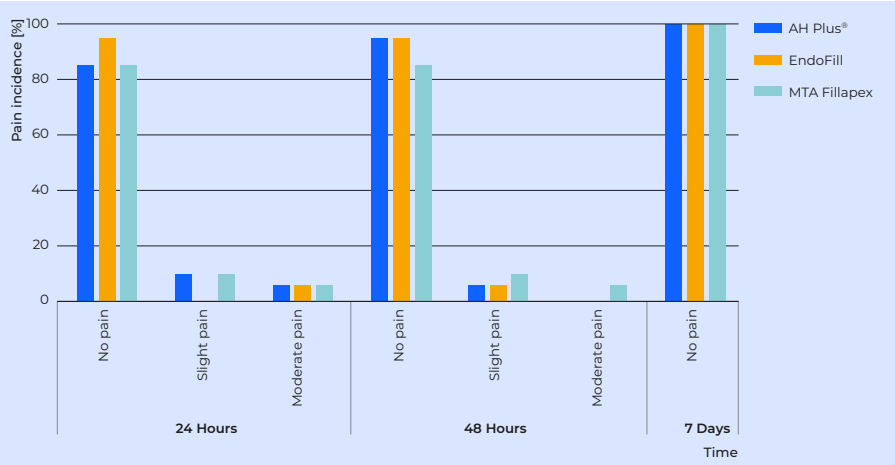
Methods: This study investigated postoperative pain and analgesic consumption following root canal treatment using three sealers: AH Plus®, EndoFill (Dentsply, Petrópolis Ind. e Com., Rio de Janeiro, Brazil), and MTA Fillapex (Angelus, Londrina,

Brazil). A total of 60 teeth were treated (N=20 per group) using Wave-One® Gold files (Dentsply Maillefer, Ballaigues, Switzerland) under 2.5% sodium hypochlorite irrigation. Obturation was performed using the single cone and vertical compaction technique. The pain levels were recorded via a pain intensity on a scale from 1 to 4 at 24 hours, 48 hours, and 7 days post-treatment.

Results: Overall, most patients reported no pain or only slight pain across all groups. For AH Plus®, 85% of patients reported no pain on the first 24h and 95% of them had no

pain 48h after treatment. For Endo-Fill, 95% of patients had no pain at 24h and 48h. For MTA Fillapex, 85% of patients presented no pain at 24h and 48h. Seven days after the treatment, no pain was reported by all patients (**Figure 5**). No significant differences were observed among the groups regarding postoperative pain incidence or intensity, nor in analgesic use. The study concluded that AH Plus®, EndoFill, and MTA Fillapex resulted in similar outcomes regarding postoperative pain and analgesic intake [21].

Figure 5:
Postoperative pain severity over time in teeth treated with AH Plus®, EndoFill, and MTA Fillapex. No significant differences between sealers (Chi-square test).



Study 17

Title: Influence of sonic activation of epoxy-resin and calcium silicate sealer on postoperative pain: a patient-blinded, parallel group, randomized clinical trial.

Authors: Yilmaz K, Sari M.

Published in: BMC Oral Health. 2024 Oct 23;24(1):1268.

Methods: This study aimed to compare postoperative pain after single-visit root canal treatments (RCT) using two types of sealers – epoxy-resin-based AH Plus® and calcium silicate-based Endosequence BC sealer (Brasseler, Savannah, GA, USA) – with or without

sonic activation. A total of 72 patients were included (18 per group), all of whom had asymptomatic apical periodontitis in mandibular premolars. Obturation was performed using single cone technique. A master cone was coated with the sealer and inserted in the canal for AH Plus®, whereas Endosequence BC sealer was directly injected in the canal and the gutta-percha was inserted after. The postoperative pain levels were recorded on days 1, 2, 3, and 7 using a numeric rating scale (NRS) ranging from 0 (no pain) to 10 (worst pain). Pain intensity was categorized as none, mild, moderate, or severe. Additionally, analgesic intake was recorded.

Results: The results showed no statistically significant differences in postoperative pain scores or analgesic consumption between the two sealers (AH Plus® vs. Endosequence BC sealer) or between the sonic activation and non-activation groups ($p>0.05$). The highest incidence of moderate pain occurred at 24 hours, but no patients required analgesics after 24 hours. By 48 hours, no patients reported pain. Both AH Plus® and Endosequence BC sealers led to similar levels of postoperative pain, and sonic activation did not influence pain outcomes [22].

Study 18

Title: The effect of two calcium silicate-based and one epoxy resin-based root canal sealer on postoperative pain: a randomized controlled trial

Authors: Aslan T, Dönmez Özkan H.

Published in: Int Endod J. 2021 Feb;54(2):190-197.

Methods: This study aimed to compare the postoperative pain levels following single-visit root canal treatments using two calcium silicate-based sealers (Endoseal MTA (Maruchi, Wonju, South Korea) and

EndoSequence BC sealer (Brasseler, Savannah, GA, USA)) and one epoxy resin-based sealer (AH Plus®). A total of 90 patients diagnosed with mandibular first or second molars with asymptomatic irreversible pulpitis were divided into three groups of 30 based on the sealer used. Root canals were instrumented with Reciproc files (VDW, Munich, Germany), irrigated with 5% sodium hypochlorite and 17% EDTA, and obturated using the single cone technique. The sealers were applied using paper points and then a single tapered gutta-percha was adapted to the root canal. Post-

operative pain was assessed using a Visual Analog Scale (VAS) at multiple time points: 6, 12, 24, 48, 72 hours, and 7 days.

Results: The study found that pain intensity peaked at 6 hours and significantly decreased after 12 hours across all groups. No significant differences in pain levels or analgesic intake were observed between the groups at any time point. Overall, all three sealers resulted in similar postoperative pain levels, with no pain reported by 24 hours post-treatment [23].

Study 19

Title: Assessment of Extrusion and Postoperative Pain of a Bioceramic and Resin-Based Root Canal Sealer.

Authors: Fonseca B, Coelho MS, Bueno CEDS, Fontana CE, Martin AS, Rocha DGP.

Published in: Eur J Dent. 2019 Jul;13(3):343-348.

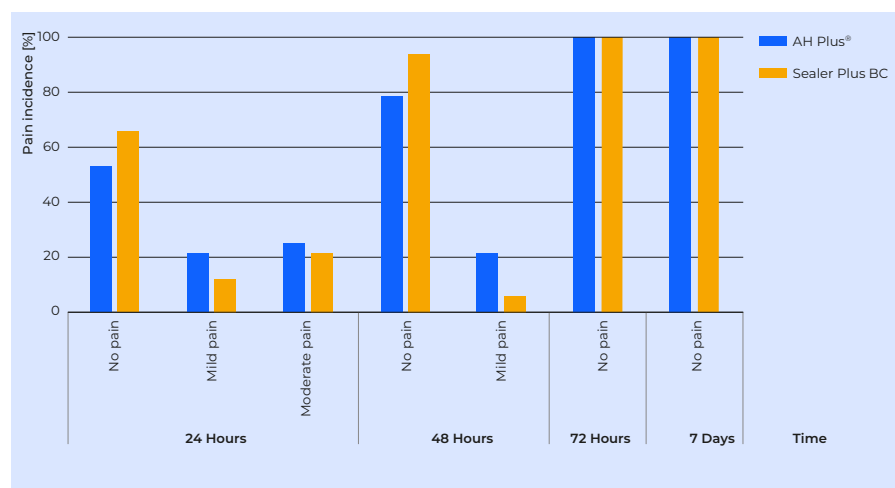
Methods: This study compared the extrusion rates and postoperative pain associated with a bioceramic sealer (Sealer Plus BC (MKLife Medical and Dental Products, Porto Alegre, Brazil)) and a resin-based sealer (AH Plus®) in patients under-

going endodontic treatment for pulpal necrosis in single-rooted maxillary anterior teeth. A total of 64 patients were included, with 32 in each group. Root canal treatments were performed using Reciproc file system (VDW, Munich, Germany), under 2.5% sodium hypochlorite irrigation and 17% EDTA. For obturation, AH Plus® was applied with a lentulo and Sealer Plus BC was inserted with a syringe. The root canals were obturated using single cone technique. Pain and sealer extrusion were evaluated at 24 hours, 48 hours, 72 hours, and one-week post-treatment using a Visual Analog Scale (VAS).

Results: Results showed that the Sealer Plus BC had a significantly higher extrusion rate (59.37%) compared to the resin-based sealer (28.12%) ($p < 0.05$). However, there was no correlation between sealer extrusion and postoperative pain levels for either group. After 24 hours, 53.13% of patients in the AH Plus® group reported no pain, while 65.63% in the Sealer Plus BC group reported the same (**Figure 6**). By 48 hours, no pain was reported in either group (**Figure 6**). Overall, both sealers demonstrated similar levels of postoperative pain and analgesic intake [24].

Figure 6:

Pain incidence over time in the study by Fonseca, Coelho (24). There were no statistically significant differences between sealers.



4 Main outcomes from the selected studies

Study 20

Title: The effect of bioactive glass-based, bioceramic based and epoxy amine resin-based root canal sealers on post-obturation pain: A double blinded randomized controlled trial.

Authors: Nagpal R, Taneja S, Bhalla VK.

Published in: J Conserv Dent Endod. 2024 Jun;27(6):591-597.

Methods: This study aimed to compare the effects of two calcium silicate-based sealers (Bio-C Sealer Ion+ (Angelus, Londrina, PR, Brazil) and Nishika Canal Sealer BG (Nippon Shika Yakuhin Co., Ltd., Yamaguchi, Japan)) and one epoxy resin-based sealer (AH Plus®) on postoperative

pain and analgesic intake following single-visit root canal treatment. In this study, 29 patients with symptomatic irreversible pulpitis and symptomatic apical periodontitis were included in each of the three groups (29 per group). Canals were instrumented with Protaper Gold® file system (Dentsply Maillefer, Ballaigues, Switzerland) and irrigated with 2.5% sodium hypochlorite and 17% EDTA. After applying the sealers to the master gutta-percha cone, root canals were obturated using single cone technique. Postoperative pain was assessed using a Visual Analog Scale (VAS) at 6 hours, 24 hours, 48 hours, 5 days, and 7 days after the treatment.

Results: The results indicated that Bio-C Sealer Ion+ had the lowest pain scores, followed by Nishika Canal Sealer BG and AH Plus®, with significant differences in pain levels at 6 hours ($p<0.001$) and 24 hours ($p=0.028$). No significant differences were observed at 48 hours, 5 days, or 7 days. Bio-C Sealer Ion+ group required significantly less analgesic intake compared to the other groups ($p=0.022$). In summary, calcium silicate-based sealers resulted in significantly lower levels of postoperative pain compared to the epoxy resin-based AH Plus® at the 6-hour and 24-hour intervals, while the analgesic intake was also lower for the Bio-C Sealer Ion+ group. No pain was reported after 5 days for any of the sealers [25].



Take home message

In single cone obturation, AH Plus® was associated with mild to moderate pain that decreased after 48 hours. In most cases, analgesic intake was not associated with the use of AH Plus®. There was no difference in pain intensity in comparison with bioceramic and zinc-oxide and eugenol-based sealers in most studies.

e. Non-specified obturation techniques

Study 21

Title: Postobturation Pain Associated with Tricalcium Silicate and Resin-based Sealer Techniques: A Randomized Clinical Trial

Authors: Tan HSG, Lim KC, Lui JN, Lai WMC, Yu VSH.

Published in: J Endod. 2021 Feb;47(2):169-177.

Methods: This study examined the incidence and intensity of post-obturation pain associated with two sealers – AH Plus® and TotalFill BC sealer (FKG Dentaire SA, La Chaux-de-

Fonds, Switzerland) – over a period of 7 days. This trial included 83 teeth in the AH Plus® group and 80 in the TotalFill BC group. The included teeth were either vital, nonvital, or previously root filled. Most treatments were performed over two visits, with root canal instrumentation using nickel-titanium rotary files and irrigation with 1.25% sodium hypochlorite and 17% EDTA. Pain severity was recorded at 24 hours, 72 hours, and 7 days post-treatment using a 5-point Likert scale.

Results: A total of 19.3% of patients experienced pain 24 h after the treatment, decreasing to 9.6% at 72 h with AH Plus®. For TotalFill BC sealer, pain

was reported by 22.5% of patients at 24 h and by 10.0% at 72h. About 96.4% and 92.5% of patients treated with AH Plus® and TotalFill BC sealer reported no pain 7 days after treatment, respectively. There was no significant difference in pain incidence nor severity between the two groups. Factors such as preoperative pain severity, pulp status, and sonic activation during treatment were identified as potential prognostic indicators for post-obturation pain. In sum, the incidence of post-obturation pain was mild and similar across both sealing materials, indicating that the choice of sealer did not significantly affect pain outcomes following root canal treatment [26].

Study 22

Title: Comparative evaluation of the effect of calcium silicate and epoxy resin-based root canal sealers on postoperative pain in patients with primary endodontic lesion: A randomized clinical study.

Authors: Supreet K, Kishan KV, Shah NC, Shah R, Shroff MG, Volety S.

Published in: J Conserv Dent. 2023 Mar-Apr;26(2):194-198.

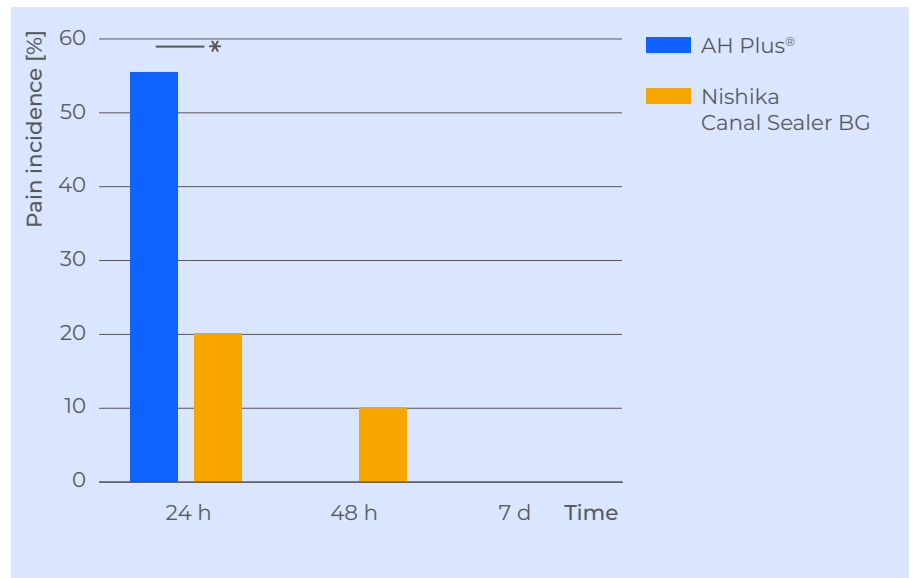
Methods: This study aimed to compare postoperative pain severity between a bioceramic sealer (Nishika canal sealer BG (Nippon Shika Yakuhin Co., Ltd., Yamaguchi, Japan)) and an epoxy resin-based sealer (AH Plus®) in patients with primary endodontic lesions. A total of 40 healthy individual with asymptomatic necrotic pulp in first and second molars were included. The root canal treatments were performed in two visits, using Hyflex CM files (Coltene-Whaledent, Altstätten, Switzerland), and irrigating with 2.5% NaOCl and 17% EDTA. Pain was assessed at 24 hours, 48 hours, and 7 days post-obturation using a Visual Analog Scale (VAS).

Results: Approximately 55% of AH Plus® patients reported pain after 24 hours versus 20% for Nishika Canal Sealer BG. Pain Incidence decreased over time for both groups, and, after 48 hours, no patients in the AH Plus® group reported pain. However, the Nishika BG group experienced significantly lower pain scores at the 24-hour mark ($p=0.022$) compared to AH Plus®, though there were no significant differences at the 48-hour and 7-day assessments (**Figure 7**). By day 7, neither group reported pain. In conclusion, while Nishika canal sealer BG led to significantly less pain than AH Plus® at 24 hours, both sealers showed similar outcomes in terms of postoperative pain at later time points [27].

Figure 7:

Pain incidence over time for AH Plus® and Nishika Canal Sealer BG.

* - significant differences between the sealers (Chi-square test, $p=0.022$).



Take home message

Conclusion: From the 22 studies included in this chapter, the reported findings do not indicate a significant post-operative difference between AH Plus® and other sealers, nor does it suggest that the obturation technique influences post-operative pain. Independently of the obturation technique or sealer, pain seems to significantly decrease after 48h to 72h, with most patients experiencing little to no pain after 7 days.

2. Clinical and radiographic success

The evaluation of the clinical and radiographic success of endodontic primary and secondary treatments is vital to ensure that the treatment is effectively solving the infection, healing the periapical lesion and preserving tooth function. Twenty-four of the included studies evaluated the clinical and radiographic healing of the lesion. The studies that evaluated clinical parameters included criteria such as the absence/presence

of spontaneous pain, swelling, tenderness to percussion and palpation, and the periodontal probing depth. The studies that included a radiographic evaluation measured the area of periapical lesion before and after treatment, presence/absence of periapical lesion, the periapical index (PAI) (scored from 1 to 5), and presence/absence of sealer extrusion. The success rate of the treatments was also presented and authors often considered the tooth as healed (the periapical lesion completely disap-

peared in the radiograph/no clinical symptoms), healing (the periapical lesion showed a reduction in the size of the lesion without complete disappearance in the radiograph; no clinical symptoms), or non-healing (the periapical lesion size remained or increased after treatment in the radiograph; and/or clinical symptoms). Some of the articles featured in this section can also be found in the previous section since they also address postoperative pain measurement (studies 4, 9, 10, 11, 13, 14, and 15).

Table 4:
Mean size and standard deviation (in mm²) of the periapical lesion over time for the different sealers.

Sealer	Time	Mean±SD (mm ²)	p-value ^{1,2}
Tubli-Seal	Baseline	15.25±13.52	0.001
	1 month	13.72±13.67	
	3 months	10.44±11.04	
	6 months	4.33±6.47	
AH Plus®	Baseline	14.47±11.66	0.001
	1 month	11.5±8.87	
	3 months	8.72±9.05	
	6 months	2.77±5.13	
BioRoot RCS	Baseline	15.35±12.86	0.001
	1 month	13.55±13.26	
	3 months	9.69±11.7	
	6 months	2.55±4.51	

¹ Friedman's Two-way Analysis of Variance. ² Intragroup analysis over time.

a. Cold lateral compaction

Study 4*

Title: Comparative evaluation of postoperative pain and periapical healing after root canal treatment using three different base endodontic sealers – A randomized control clinical trial.

Authors: Khandelwal A, Jose J, Teja KV, Palanivelu A.

Published in: J Clin Exp Dent. 2022 Feb 1;14(2):e144-e152.

Methods: For more details, refer to study 4 on page 10.

Results: There was no difference in the mean area of periapical lesions at baseline, but significant reductions were observed after 3 and 6 months for all groups ($p=0.001$) (Table 4). BioRoot RCS showed the best healing, with a mean difference in the size of periapical lesions from baseline to 6 months of 12.8 mm², compared to 10.92 mm² with Tubli-Seal and 11.7 mm² with AH Plus®

(Table 4). In sum, all sealers improved periapical healing 3 and 6 months after treatment [9].

Study 23

Title: Radiographic evaluation of periapical healing of permanent teeth with periapical lesions after extrusion of AH Plus® sealer.

Authors: Sari S, Duruturk L

Published in: Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007 Sep;104(3):e54-9.

Methods: The study aimed to clinically and radiographically assess the effects of AH Plus® sealer extrusion on the healing of teeth with asymptomatic apical periodontitis. The study comprised 87 participants (49 in the sealer extrusion group and 38 in the control group). The mean age

of the patients was 12 years (age range: 9-15 years). The obturation technique used was lateral condensation, and healing was monitored at 3 and 6 months, 1, 2, 3, and 4 years using clinical and radiographic assessments. The success of treatment was categorized into three groups: “complete healing” (no clinical symptoms and normal periodontal ligament space on radiographs), “incomplete healing” (no symptoms but reduction in lesion size), “no healing” (acute symptoms or no change/increase in lesion size on radiographs).

Results: At the 4-year follow-up, the sealer extrusion group had 83.67% of teeth with complete healing, 8.16%

with incomplete healing, and 8.16% with no healing. The control group showed 89.47% complete healing and 10.53% no healing. The difference in complete healing between the two groups was statistically significant at the 6-month follow-up, but not at the 4-year mark. The amount of extruded sealer material showed no significant difference in healing outcomes. The study concluded that while AH Plus® sealer extrusion does not prevent periapical healing, it can delay the healing process, particularly in children. Additionally, resorption of the extruded material was not necessary for healing to occur [28].

* Study also included in the post-obturation pain section

Study 24

Title: Apically Extruded Sealers: Fate and Influence on Treatment Outcome.
Authors: Ricucci D, Rôças IN, Alves FR, Loghin S, Siqueira JF Jr
Published in: J Endod. 2016 Feb;42(2):243-9.

Methods: The study investigated the outcomes of unintentional extrusions in root canal treatments using various sealers. A total of 105 patients with follow-ups at 1, 2, and more than 4 years, using sealers such as AH Plus® (N=20), Apexit (Ivoclar Vivadent, Schaan, Liechtenstein) (N=15), Endomethasone (Septodont, Saint-Maur-des-Fosses, France) (N=15), zinc oxide and eugenol pulp canal sealer (Sybron Dental, Orange, CA, USA) (PCS; N=28), zinc oxide and eugenol pulp canal sealer extended working time (Sybron Dental, Orange, CA, USA) (PCS EWT; N=21), and Tubli-Seal (Sybron Dental, Orange, CA, USA) (N=6). Both vital and necrotic teeth were treated, using hand instruments and 1% sodium hypochlorite for irrigation. The results from this study came from radiographic comparisons, which applied Strindberg's criteria to evaluate treatment outcomes based on periodontal health.

Results: The study showed that 100% of teeth without apical periodontitis were classified as healed at four follow-ups. Among teeth with apical periodontitis, healing rates were of 78% for AH Plus®, 82% for Apexit, 89% for Endomethasone, 67% for PCS, 91% for PCS EWT, and 80% for Tubli-Seal. All cases of extrusion with Tubli-Seal demonstrated complete removal of extruded material one year after, while PCS and PCS EWT showed 43% and 36% removal, respectively. At two years, AH Plus® and Apexit had significantly lower removal rates compared to other sealers ($p<0.05$) (**Table 5**). Overall, while not all extruded materials were completely removed, zinc oxide-eugenol-based sealers were removed faster than AH Plus® and Apexit. The type of extruded sealer did not significantly affect treatment outcomes if root canals were adequately treated [29].

Table 5:
Periapical resorption rates of each sealer after 1, 2, and >4 years.

	1 year	2 years	>4 years
AH Plus®	7.1%	5.9%	15%
Apexit	22.2%	0%	33.3%
Endomethasone	22.2%	55.6%	86.7%
PCS	42.9%	52.6%	82.1%
PCS EWT	35.7%	52.6%	71.4%
Tubli-Seal	100%	100%	100%

Study 25

Title: Comparison between AH Plus® sealer and total fill bioceramic sealer performance in previously untreated and retreatment cases of maxillary incisors with large-sized periapical lesion: a randomized controlled trial.

Authors: Wahbi E, Achour H, Alsayed Tolibah Y.

Published in: BDJ Open. 2024 Sep 12;10(1):73.

Method: This study aimed to evaluate the efficacy of a bioceramic (Total-Fill BC Sealer (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland)) sealer using the single cone technique (SCT) compared to AH Plus® sealer applied with the cold lateral condensation technique (LCT) in treating large periapical lesions (greater than 5 mm) in both untreated and retreatment cases involving maxillary anterior teeth. A total of 41 patients with 60 permanent incisors (30 untreated and 30 retreated) were included (N=15 teeth per group). Preoperative radiographs assessed lesion size and tooth anatomy. The study measured the periapical lesion diameter at 6- and 12-months post-treatment, categorizing outcomes into four groups: healed, healing, doubt, and failure, based on radiographic assessments.

Results: After 6 months, AH Plus® led to 86.67% healing in untreated cases and 100% healing/healed cases in retreatment cases. After 12 months, healing/healed rates were of 93.34% for untreated and 100% for retreated cases. Statistical analyses indicated no significant differences in apical lesion sizes or success rates between the groups at any time point, suggesting that both sealers performed similarly in promoting healing of periapical lesions, regardless of whether the teeth were untreated or had previously undergone endodontic treatment [30].

Study 26

Title: Clinical outcome of non-surgical root canal treatment using different sealers and techniques of obturation in 237 patients: A retrospective study

Authors: Radwanski M, Pietrzycka K, Eyüboğlu TF, Özcan M, Lukomska-Szymanska M.

Published in: Clin Oral Investig. 2024 Aug 10;28(9):479.

Methods: This retrospective study aimed to compare the clinical outcomes of two root canal sealers (AH Plus® and AH Plus® Bioceramic Sealer (Dentsply DeTrey GmbH, Konstanz, Germany)) and three obturation techniques (cold lateral condensation and continuous wave compaction with AH Plus®, and single cone with AH Plus® Bioceramic Sealer) in root canal treatments. A total of 283 teeth were included, with a minimum follow-up of 6 months and maximum of 30 months. For re-treatment cases, the obturation was first removed using an ultrasonic tip and HyFlex™ Remover (Coltene-Whaledent, Altstätten, Switzerland); then ProTaper Next® (Dentsply Maillefer, Ballaigues, Switzerland) was used for instrumentation. Irrigation was done with 5.25% sodium hypochlorite. Success criteria were defined radiographically using the Periapical Index (PAI) (scores 1 or 2 as success and 3 to 5 as failure). Based on loose criteria, "success" included all healed and healing teeth, whereas „failure“ included all non-healed teeth. According to strict criteria, only healed cases were classified as „success“.

Results: The success rates were similar for both sealers, with AH Plus® achieving 94.2% and AH Plus® Bioceramic Sealer 94.74% under loose criteria. Strict criteria showed the highest success rate for teeth with vital pulp (96.7%), followed by necrotic (83.1%) and retreated teeth (82.6%). Cold lateral condensation (CLC) had a higher success rate (92.4%) compared to continuous wave compaction (CWC, 82.0%) and single cone (SBO, 85.5%). Sealer extrusion was more common in CWC and SBO compared to CLC and negatively impacted treatment success. Overall, the study concluded that both sealers had comparable effectiveness. Factors such as pulp necrosis, secondary treatment, and sealer extrusion were identified as predictors of healing delay and may contribute to treatment failure [31].

Study 27

Title: Comparative analysis of carrier-based obturation and lateral compaction: a retrospective clinical outcomes study.

Authors: Hale R, Gatti R, Glickman GN, Opperman LA.

Published in: Int J Dent. 2012;2012:954675.

Methods: This study compared the outcomes of primary endodontic treatment using lateral condensation (LC) and carrier-based obturation (CBO) techniques. It included 71 patients, with vital or necrotic teeth, all of whom had permanent restorations or full-coverage crowns. The root canals were cleaned and shaped using ProFile® instruments (DENTSPLY Tulsa Dental, Tulsa, OK, USA), and the obturation was performed with either LC or CBO and with AH Plus® sealer. The average follow-up period was 28 months, with clinical and radiographic assessments conducted to determine success, defined as the absence of symptoms and healing or reduction in periapical radiolucency.

Results: The results showed that the success rates for the CBO and LC groups were very similar, with 83% success in the CBO group and 81% in the LC group. There was no significant difference between the two techniques ($p=0.802$). The success of treatment was significantly associated with the tooth location in the arch, with molars having a much lower success rate (53%) compared to premolars and anterior teeth (89%) ($p=0.005$). Additionally, the LC group had a higher incidence of voids in the obturation, though this did not significantly impact the overall success rates. In conclusion, both lateral condensation and carrier-based obturation techniques yielded similar success rates [32].

4 Main outcomes from the selected studies

Table 6:

Summary of the success rates of studies using AH Plus® in obturations with the cold lateral condensation technique.

Author	Number of cases	Number of failures of AH Plus®	Follow-up period	Success rate of AH Plus®	Success rate of the competitor	Significant differences between groups
Khandelwal, Jose (9)	AH Plus® (N=18); Tubli-Seal (N=18); BioRoot RCS (N=18)	-	Baseline, 24h, 48h, 72h, 7d, 1, 3 and 6 m	Reduction of size of lesion observed at 3 and 6 months for all the test groups (p=0.001)	-	-
Sari and Duruturk (28)	AH Plus® (N=49 in sealer extrusion group, N=38 in control group)	After 4 years (extrusion): 4/49 After 4 years (no extrusion): 4/38	3 and 6 months and 1, 2, 3, and 4 years	After 4 years: treatment was rated as complete healing in 41 canals (83.67%), incomplete healing in 4 canals (8.16%), and no healing in 4 canals (8.16%) in the extrusion group. In the non-extrusion group, treatment was rated as complete healing in 34 canals (89.47%) and no healing in 4 canals (10.53%).	-	More complete healing was observed in the control group 6 months after treatment (p<0.05), but not at any of the other time points.
Ricucci, Rôças (29)	AH Plus® (N=20), Apexit (N=15), Endomethasone (N=15), PCS (N=28), PCS EWT (N=21), Tubli-Seal (N=6)	1 st year: 1 in 11 2 nd year: 2 in 16 4 th year: 4 in 18	1, 2 and >4 years	In teeth without AP: 100% healed after 4 years. In teeth with AP: 78% healed after 4 years.	In teeth without AP: 100% healed after 4 years. In teeth with AP: Apexit: 82%, Endomethasone: 89%, PCS: 67%, PCS EWT: 91%, Tubli-Seal: 80%	No differences in the outcome between the sealers.
Wahbi, Achour and Alsayed Tolibah (30)	60 permanent incisors divided in 4 groups (N=15 per group): AH Plus® in retreatment and primary treatment; Total Fill BC Sealer in retreatment and primary treatment	1 st year: Primary RCT: 1; Retreatment: 0	6 and 12 months	6 months: Primary treatment: 86.67% healing; Retreatment: 93.33% healing and 6.67% healed 12 months: Primary treatment: 46.67% healing and 46.67% healed; Retreatment: 60% healing and 40% healed	6 months: 80.0% healing and 13.3% healed (treatment) and 80.0% healing and 6.67% healed (retreatment) 12 months: 73.33% healing and 20% healed (treatment) and 66.67% healing and 26.67% healed (retreatment)	No differences between sealers.
Radwanski, Pietrzycka (31)	AH Plus® (N=207); AH Plus® Bioceramic (N= 76)	Loose criteria: 12/207; Strict criteria: 26/207	6 months	Loose criteria: AH Plus® + Cold lateral condensation: 94.07% AH Plus® + Continuous wave compaction: 94.38% Strict criteria: AH Plus® + Cold lateral condensation: 92.37% AH Plus® + Continuous wave compaction: 82.02%	Loose criteria: AH Plus® Bioceramic + single cone: 94.74% Strict criteria: AH Plus® Bioceramic + single cone: 85.53%	No differences between sealers.
Hale, Gatti (32)	Lateral condensation: N=36; Carrier-based obturation: N=35	LC: 6/36 CBO: 7/35	Average: 28 months	A total of 6 teeth were classified as failures in the CBO group. A total of 7 teeth were classified as failures in the LC group.	-	No differences between techniques.



Take home message

AH Plus® shows acceptable performance when used in lateral condensation technique on a similar level to competitor sealers. Lastly, AH Plus® can be used for lateral condensation for both primary endodontic treatments and retreatments.

b. Carrier-based obturation

Study 27

Title: Comparative analysis of carrier-based obturation and lateral compaction: a retrospective clinical outcomes study.

Authors: Hale R, Gatti R, Glickman GN, Opperman LA.

Published in: Int J Dent. 2012; 2012:954675.

Methods: For more details, refer to study 27 on page 35.

Results: The results showed that the success rates for the CBO and LC groups were very similar, with 83% success in the CBO group and 81% in the LC group. There was no significant difference between the two techniques ($p=0.802$). The success of treatment was significantly associated with the tooth location in

the arch, with molars having a much lower success rate (53%) compared to premolars and anterior teeth (89%) ($p=0.005$). Additionally, the LC group had a higher incidence of voids in the obturation, though this did not significantly impact the overall success rates. In conclusion, both lateral condensation and carrier-based obturation techniques yielded similar success rates [32].

Study 30

Title: Survival and periapical health after root canal treatment with carrier-based root fillings: five-year retrospective assessment.

Authors: Pirani C, Friedman S, Gatto MR, Iacono F, Tinarelli V, Gandolfi MG, Prati C.

Published in: Int Endod J. 2018 Apr;51 Suppl 3:e178-e188.

Methods: This study aimed to evaluate the 5-year prognosis of root canal treatments using Thermafil® root fillings (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), with a focus on survival rates and periapical health. The study included 213 teeth from 94 patients, all of whom had undergone primary root canal treatment or retreatment with Thermafil® obturators and AH Plus® sealer. Teeth with adequate oral hygiene, probing depth ≤ 5 mm, and definitive restorations within 2 weeks post-treatment were eligible. Clinical and radiographic assessments were made over a 5-year period, focusing on signs of infection (pain, swelling, sinus tract, tenderness) and periapical healing using PAI scores. Root filling length and voids in the obturation were also assessed.

Results: Of the 213 treated teeth, 193 (91%) were included in the analysis, with 164 teeth (85%) classified as 'healthy' and 29 teeth (15%) showing persistent infection. Factors significantly associated with 'healthy' status included preoperative pulpal/periapical diagnosis, PAI score, and adequate root filling length. The type of coronal restoration, tooth location, and use of posts had no significant effect on the outcome. Multilevel analysis showed that the PAI score was the only predictor of periapical health ($p=0.032$). The 5-year survival and health outcomes for Thermafil® root-filled teeth were comparable to those reported for conventional root fillings, supporting the clinical use of Thermafil® as an effective root filling material [33].

Table 7:

Summary of the success rates of studies using AH Plus® in obturations with the carrier-based obturation technique.

Author	Number of cases	Number of failures of AH Plus®	Follow-up period	Success rate of AH Plus®	Success rate of the competitor	Differences between groups
Hale, Gatti (32)	Lateral condensation (LC): N=36; Carrier-based obturation (CBO): N=35	LC: 6/36 CBO: 7/35	Average: 28 months	A total of 6 teeth were classified as failures in the CBO group. A total of 7 teeth were classified as failures in the LC group.	-	No difference between techniques.
Pirani, Friedman (33)	AH Plus® (N=213)	29/193	5±1 years	A total of 193 of 213 teeth (91%) observed for the period of 5 1 years were included in the statistical analysis, with 164 of 193 teeth (85%) clinically and radiographically assessed as 'healthy' and 29 of 193 teeth (15%) assessed as 'diseased' because of persistent endodontic infection.	-	-



Take home message

AH Plus® presented long-term favorable success rates when used in carrier-based obturation techniques. Factors such as the periapical condition before the treatment seem to negatively impact the treatment outcomes.

4 Main outcomes from the selected studies

c. Warm obturation
(without a carrier)

Study 9*

Title: Comparative evaluation of pain, tenderness and swelling followed by radiographic evaluation of periapical changes at various intervals of time following single and multiple visit endodontic therapy: an in vivo study.
Authors: Prashanth MB, Tavane PN, Abraham S, Chacko L.
Published in: J Contemp Dent Pract. 2011 May 1;12(3):187-91.

Methods: For more details, refer to study 9 on page 15. were vital or nonvital [14].

Results: There were no significant differences in postoperative pain, tenderness, or swelling between the single-visit and multiple-visit treatment groups. Radiographic evaluation also showed no differences between the groups in terms of periapical healing or lesion resolution. In conclusion, there was no significant difference between single-visit and multiple-visit endodontic therapy, regardless of whether the teeth

Study 10*

Title: The efficacy of 3 root canal sealers combined with warm gutta-percha vertical compression technique in the treatment of dental pulp disease.
Authors: Li W, Ju B, Cheng G, Lv Z.
Published in: Medicine (Baltimore). 2024 Jun 14;103(24):e38414.

Methods: For more details, refer to study 10 on page 16.

Results: After 6 months, the efficacy rate for iRoot SP was 96.67%, for GuttaFlow was 90.00% and for AH Plus® was 81.67% (p<0.05 versus iRoot SP). The average filling times were significantly longer for AH Plus® (78.95 seconds) compared to GuttaFlow (37.26 seconds) and iRoot SP (36.89

seconds). IL-6 and TNF-α levels significantly decreased in all groups post-treatment, but AH Plus® exhibited higher levels compared to the other sealers. The study concluded that iRoot SP and GuttaFlow were more effective than AH Plus® in achieving apical closure, reducing filling time, and minimizing postoperative pain and inflammation [15].

* Study also included in the post-obturation pain section

Study 11*

Title: Clinical Efficacy of Sealer-based Obturation Using Calcium Silicate Sealers: A Randomized Clinical Trial
Authors: Kim JH, Cho SY, Choi Y, Kim DH, Shin SJ, Jung IY.

Published in: J Endod. 2022 Feb;48(2):144-151.

Methods: For more details, refer to study 11 on page 17.

Results: Both techniques presented similar success rates: 92.3% for AH Plus® (CWC) and 94.3% for Endoseal TCS (SBO) based on loose criteria. Strict criteria showed 51.3% success rate for AH Plus® and 71.4% for Endo-

seal TCS [16].

Study 29

Title: Outcome of Root Canal Treatments Using a New Calcium Silicate Root Canal Sealer: A Non-Randomized Clinical Trial.

Authors: Zavattini A, Knight A, Foschi F, Mannocci F.

Published in: J Clin Med. 2020 Mar 13;9(3):782.

Methods: This study compared the success rates of root canal treatments using two different sealing methods: calcium silicate sealer (BioRoot® RCS (Septodont, Saint Maur Des Fosses, France)) with single cone technique versus epoxy-resin-based cement (AH Plus®) with warm vertical condensation. A total of 63 teeth with irreversible pulpitis or necrotic pulp were treated with each sealer (N=126 teeth). Treatments were performed in a single visit, with root canal preparation done using Protaper Next® (Dentsply Maillefer, Ballaigues, Switzerland) and 2% sodium hypochlorite irrigation. Success was eva-

luated through clinical assessments and radiographic analysis after 12 months, with criteria based on functional status and periapical radiolucency changes.

Results: The success rate for the AH Plus®/warm vertical condensation group was 80% using cone beam computerized tomography (CBCT) and 89% with periapical radiographs. For the BioRoot RCS/single cone group, the rates were 84% (CBCT) and 90% (radiographs). Overall, both sealers were equally effective in root canal treatments [34].

Study 30

Title: Outcome of root canal treatment using warm vertical compaction with bioceramic and resin-based sealers: A randomized clinical trial

Authors: Hu J, Zhu Y, Deng S, Wang Z, He F

Published in: Aust Endod J. 2023 Sep;49 Suppl 1:170-178.

Methods: This study compared the effects of a bioceramic sealer (iRoot SP (Innovative BioCeramix Inc., Vancouver, Canada)) and a resin-based sealer (AH Plus®) on root canal treatment outcomes over a two-year follow-up period. It included 76 teeth with irreversible pulpitis or necrotic pulp. The treatments were done using Protaper® files (Dentsply Maillefer, Ballaigues, Switzerland), irrigation with 3% sodium hypochlorite and 17% EDTA, followed by warm vertical compaction technique for obturation. Outcomes were assessed clinically and radiographically at 6, 12, and 24 months using the periapical index (PAI) to classify success (asymptomatic teeth with PAI scores of 1-2) or failure (symptomatic teeth with 3-5 PAI scores).

Results: Results showed success rates of 85% for the iRoot SP group, and 88.2% for the AH Plus® group at 24 months after treatment. No significant differences between the two groups were observed in any of the time points. AH Plus® exhibited a higher rate of sealer extrusion (44.2%) compared to iRoot SP (16.5%). Overall, iRoot SP demonstrated comparable clinical success and radiographic outcomes to AH Plus® over the two years [35].

Study 31

Title: Clinical and Patient-centered Outcomes of Nonsurgical Root Canal Retreatment in First Molars Using Contemporary Techniques.

Authors: He J, White RK, White CA, Schweitzer JL, Woodmansey KF

Published in: J Endod. 2017 Feb;43(2):231-237.

Methods: The study aimed to evaluate the outcomes of nonsurgical endodontic retreatment in first molars using contemporary techniques. The included patients had previously undergone endodontic treatment for maxillary or mandibular first molars. The study compared two groups: 22 teeth treated with AH Plus®/gutta-percha and 30 with Resilon (Pentron Clinical Technologies, Wallingford, CT, USA)/RealSeal (SybronEndo, Orange, CA, USA). Retreatments were performed over 2-3 visits, during which previous obturation materials and root canal obstructions were removed using heat, solvents, hand files, rotary files, and ultrasonic instruments. Irrigation involved 5.25% sodium hypochlorite and 17% EDTA, followed by warm vertical compaction with the chosen materials. Outcomes were classified into three categories: „healed“ (absence of symptoms and normal periapical tissue), „healing“ (no symptoms but with reduced periapical radiolucency), and „nonhealing“ (presence of symptoms or unchanged/enlarged radiolucency).

Results: The success rate after two years was 90.9% for AH Plus® and 90.0% for Resilon, while the healed rate was 81.8% and 63.3%, respectively. No statistically significant differences in success or healing rates were found based on patient factors such as age, sex, or lesion size, and the type of sealer did not affect outcomes. Additionally, both overall health-related quality of life (OH-QOL) and subjective chewing ability significantly improved over time ($p<0.05$). The study concluded that endodontic retreatment using contemporary techniques resulted in a high success rate and significantly enhanced the quality of life of patients and their chewing ability [36].

Study 32

Title: The Effect of Unintentional AH-Plus Sealer Extrusion on Resolution of Apical Periodontitis After Root Canal Treatment and Retreatment-A Retrospective Case-control Study.

Authors: Martins JFB, Scheeren B, van der Waal SV

Published in: J Endod. 2023 Oct;49(10):1262-1268.

Methods: The study aimed to investigate the impact of unintentional extrusion of AH Plus® sealer on the outcomes of nonsurgical root canal treatment and retreatment in teeth with apical periodontitis (AP). The study included 120 patients divided into two groups: 60 with sealer extrusion and 60 without. Both groups consisted of single- and multi-rooted teeth diagnosed with symptomatic or asymptomatic AP, treated with gutta-percha and AH Plus®. Treatments involved either a single visit or multiple visits for complex cases, using various rotary systems for canal preparation and sodium hypochlorite and EDTA for irrigation, without intracanal medications. Outcomes were evaluated clinically and radiographically after one year, with success defined by criteria such as absence of pain, no signs of infection, and the size of the periapical lesion.

Results: Results showed that 46.7% of cases were classified as healed, 38.3% as healing, 8.3% as uncertain, and 6.7% as non-healing. Overall, 85% of cases had favorable outcomes, with initial root canal treatments achieving a 95.8% success rate compared to 73.5% for non-surgical retreatments. Importantly, the presence of AH Plus® sealer extrusion did not significantly affect treatment outcomes. No preoperative factors, including sex, age, tooth type, or location, were found to influence the results significantly. The study concluded that while sealer extrusion does not directly impact the outcome, it may contribute to delays in healing, as indicated by a 10% difference in healing rates between the groups [37].

Study 33

Title: Efficacy and retrievability of root canal filling using calcium silicate-based and epoxy resin-based root canal sealers with matched obturation techniques.

Authors: Kim SR, Kwak SW, Lee JK, Goo HJ, Ha JH, Kim HC.

Published in: Aust Endod J. 2019 Dec;45(3):337-345.

Methods: The aim of this study was to compare the efficiency of two root canal filling procedures: one using a calcium silicate-based sealer (EndoSeal MTA (Maruchi, Wonju, South Korea)) combined with the single cone technique (SCT), and the other using the continuous-wave compaction technique with AH Plus® sealer. It involved 43 patients diagnosed with irreversible pulpitis and/or apical periodontitis. The treatments required at least two visits, and instrumentation was done using Protaper® Universal files (Dentsply Maillefer, Ballaigues, Switzerland). Irrigation was performed using 5.25% sodium hypochlorite and 17% EDTA. Post-treatment evaluations focused on the quality of the filling, including the presence of voids and apical radiolucency assessed through radiographs.

Results: The study found no significant difference in the number of voids entrapped during obturation between the two techniques ($p>0.05$). Moreover, patients reported no specific clinical signs or symptoms following either obturation technique in the follow-up appointments (1 and 2 months after the treatment). In addition, SCT with EndoSeal MTA was noted to significantly shorten the filling time compared to the continuous-wave technique with AH Plus®. In conclusion, the use of the calcium silicate-based sealer with the SCT provided similar clinical efficiencies to the continuous-wave compaction technique using AH Plus®, indicating that both methods are viable options for root canal filling in mature permanent teeth [38].

4 Main outcomes from the selected studies

Table 8:

Summary of the success rates of the studies using AH Plus® in obturations with warm obturation non-carrier-based techniques.

Author	Number of cases	Number of failures of AH Plus®	Follow-up period	Success rate of AH Plus®	Success rate of the competitor	Differences between groups
Prashanth, Tavane (14)	AH Plus® (N=8 per group)	-	48h, 1, 4 and 6 weeks	-	-	-
Li, Ju (15)	AH Plus® (N=60) ; GuttaFlow (N=60); iRoot SP (N=60)	6 months: 11	1 week, 6 months	81.67%	Gutta Flow: 90.00%; iRoot: 96.67%	Differences between AH Plus® and iRoot (p<0.05).
Kim, Cho (16)	AH Plus® (N=39); Endoseal TCS (N=35)	6 months: 3	4h, 24h, and 48h; 6 months (radiographic evaluation)	Loose criteria: 92.3%; Strict criteria: 51.3%	Loose criteria: 94.3%; Strict criteria: 71.4%	No differences between sealers.
Zavattini, Knight (34)	AH Plus® (N=51); BioRoot RCS (N=53)	Cone beam computed tomography (CBCT): 10 Periapical radiograph (PA): 6	12 months	CBCT: 80% ; PA: 89%	CBCT : 84% ; PA : 90%	No differences between sealers.
Hu, Zhu (35)	AH Plus® (N=33); iRoot SP (N=43)	1 year: 3/27 2 years: 3/20	6, 12 and 24 months	6 months: 82.8% 1 year: 91.3% 2 years: 88.2%	6 months: 80% 1 year: 82.5% 2 years: 85%	No differences between sealers.
He, White (36)	AH Plus® (N=22); Resilon/RealSeal (N=30)	24 months: 4/22 (healing criteria) 24 months: 2/22 (success criteria)	6, 12, and 24 months	Success rate after 2 years: 90.9% Healed rate after 2 years: 81.6%	Success rate after 2 years: Resilon: 90.0% Healed rate after 2 years: Resilon: 63.3%	No differences between sealers.
Martins, Scheeren and van der Waal (37)	AH Plus® extrusion group (N=60) AH Plus® no extrusion group (N=60)	With extrusion: 7/60 Without extrusion: 9/60	12 months	Overall, 46.7% of cases were healed, 38.3% of cases were healing, 8.3% of cases were uncertain, and 6.7% of cases were non-healing. Favorable outcome rate for initial root canal treatment was 95.8%, whereas for nonsurgical retreatment it was 73.5%.	-	No differences between healing rate in extrusion and non-extrusion cases.
Kim, Kwak (38)	AH Plus®(N=21); EndoSeal MTA (N= 22)	-	1 and 2 months	Voids: 8/53	Voids: 5/50	No significant difference in the number of voids between sealers.

CBCT - Cone beam computed tomography; PA - Periapical radiograph



Take home message

When used for warm obturation, AH Plus® presents favourable clinical outcomes both in primary treatments and retreatments.

d. Single cone technique

Study 13*

Title: Effect of Endodontic Sealer in Young Molars Treated by Undergraduate Students - A Randomized Clinical Trial
Authors: Cunha SA, Soares CJ, Rosatto CMP, Vieira JVSM, Pereira RADS, Soares PBF, Leles CR, Moura CCG.
Published in: Braz Dent J. 2020 Nov-Dec;31(6):589-597.

Methods: For more details, refer to study 13 on page 19.
Results: There was a high incidence of apical repair, with 90.5% at one year and 89.3% at two years. Asymptomatic teeth were reported in 96.8% of cases after one year and 90.0% after two years. Failures in apical repair were linked to unsatisfactory pulpectomy and periapical conditions. The study concluded that endodontic treatment in young molars can yi-

eld satisfactory outcomes after two years, effectively preventing the loss of permanent teeth, with initial conditions being crucial for apical repair success [18].

Study 14*

Title: Pilot Evaluation of Sealer-Based Root Canal Obturation Using Epoxy-Resin-Based and Calcium-Silicate-Based Sealers: A Randomized Clinical Trial.
Authors: Song M, Park MG, Kwak SW, Kim RH, Ha JH, Kim HC.
Published in: Materials (Basel). 2022 Jul 25;15(15):5146.

Methods: For more details, refer to study 14 on page 20.
Results: Results showed no significant differences among the sealers regarding voids, sealer extrusion, or postoperative pain levels. All cases remained successful up to three months (except for one case with Adseal), with Adseal showing the most regression in periapical radiolucency.

Overall, the study found that on short term all sealers performed similarly regarding postoperative pain and effectiveness [19].

* Study also included in the post-obturation pain section

Study 15*

Title: The effect of two different root canal sealers on treatment outcome and post-obturation pain in single-visit root canal treatment: A prospective randomized clinical trial

Authors: Coşar M, Kandemir Demirci G, Çalışkan MK.

Published in: Int Endod J. 2023 Mar;56(3):318-330

Methods: For more details, refer to study 15 on page 21.

Results: The success rates were similar for both sealers: 90.9% at 12 months and 88.6% at 24 months, with no significant differences in treatment outcomes ($p>0.05$) [20].

Study 34

Title: Endodontic Outcome of Root Canal Treatment Using Different Obturation Techniques: A Clinical Study.

Authors: Winkler A, Adler P, Ludwig J, Hofmann N, Soliman S, Krastl G, Krug R.

Published in: Dent J (Basel). 2023 Aug 21;11(8):200.

Methods: This study evaluated the clinical outcomes of root canal treatment using three obturation techniques: continuous wave condensation with Resilon (CWR, Resilon Research LLC, Madison, CT, USA) (N=64 teeth), a single gutta-percha cone with AH Plus® (N=40 teeth), and a single gutta-percha cone with GuttaFlow (Coltene Whaledent GmbH + Co KG, Langenau, Switzerland) (N=10 teeth). The study included records from patients treated between 2009 and 2012, with a mean follow-up period of 6.26 years. The success of treatment was assessed using the Periapical Index (PAI), categorizing scores of 1 or 2 as successes and 3 to 5 as failures.

Results: The overall success rate was 75.4%, with the following success rates by technique: 85% for gutta-percha with AH Plus®, 80% for gutta-percha with GuttaFlow, and 68.7% for CWR. There was no statistically significant difference in success rates among the obturation techniques or between primary and retreatment cases. Nevertheless, teeth without preoperative apical lesions had a significantly higher success rate (90.7%) compared to those with lesions (66.2%). Other patient-related factors such as age, gender, and smoking did not significantly influence outcomes. Preoperative periapical status is a key prognostic factor, while the type of obturation technique or material had no significant impact on the endodontic outcome [39].

* Study also included in the post-obturation pain section

Table 9:

Summary of the success rates of studies using AH Plus® in obturations with the single cone technique.

Author	Number of cases	Number of failures of AH Plus®	Follow-up period	Success rate of AH Plus®	Success rate of the competitor	Differences between groups
Cunha, Soares (18)	AH Plus (N=35) ; Sealer 26 (N=40)	6 (after 2 years; failures of both AH Plus and Sealer 26)	12 and 24 months	1 year: apical repair was 90.5% (n=57); 2 years: apical repair was 89.3% (n=50)		
Song, Park (19)	AH Plus® (N=16); Adseal (N=18); CeraSeal (N=17); EndoSeal (N=20)	0	7 days, 1 month, 3 months	100%	AdSeal: 95.6% CeraSeal=100% EndoSeal=100%	No differences between sealers.
Cosar, Kandemir Demirci and Caliskan (20)	AH Plus® (N=44); MTA Fillapex (N=44)	5	1 and 2 years	After 1 year: 90.9% After 2 years: 88.6%	After 1 year: 90.9% After 2 years: 88.6%	No differences between sealers.
Winkler, Adler (39)	Continuous wave condensation technique with Resilon (CWR) - 64 teeth. AH Plus® + single cone (SCGP) - 40 teeth. GuttaFlow + single cone (SCGF) - 10 teeth.	6	6.26 years (4.65-8.68 years)	SCGP – 85.0%	CWR – 68.7% SCGF – 80.0%	CWR – 68.7% SCGF – 80.0%



Take home message

When used in single cone technique, AH Plus® showed high success rates throughout the studies. The absence of periapical conditions before treatment were highlighted as one of the most important prognostic factors for the success of the endodontic treatment.

e. Non-specified obturation techniques

Study 35

Title: Long-term Clinical Outcome of Teeth Obturated with Resilon

Authors: Barborka BJ, Woodmansey KF, Glickman GN, Schneiderman E, He J.

Published in: J Endod. 2017 Apr;43(4):556-560.

Methods: This study compared the long-term clinical outcomes of teeth obturated with Resilon (Resilon Research LLC, Madison, CT, USA)/Real-Seal SE (RS, (SybronEndo, Orange, CA, USA)) versus gutta-percha and AH Plus® sealer (GP). The study involved 100 patients (50 per group), all of whom had initial root canal treatments completed between 2007 and 2012, using either RS or GP. Inclusion criteria required preoperative radiographs showing no periapical radiolucency and postoperative radiographs indicating adequate obturation. The clinical success was defined as the absence of signs or symptoms, normal periapical tissues, and intact periodontal space, while failure was marked by clinical signs/symptoms or the presence of periapical radiolucency. The average follow-up was 5.8 years for RS and 6.6 years for GP.

Results: A total of 56% of RS cases were successful, compared to 88% of GP cases. The statistical analysis revealed that RS had a 5.7 times higher likelihood of failure compared to GP ($p < 0.001$). No significant association was found between outcomes and factors such as age, gender, preoperative diagnosis, or number of visits. Failed RS cases were more likely to involve root resorption and multi-rooted teeth. Teeth obturated with Resilon had significantly worse long-term outcomes compared to those obturated with gutta-percha and AH Plus® [40].

Study 36

Title: Long-term Outcomes of Endodontic Treatment Performed with Resilon/Epiphany.

Authors: Strange KA, Tawil PZ, Phillips C, Walia HD, Fouad AF

Published in: J Endod. 2019 May;45(5):507-512.

Methods: The study aimed to radiographically evaluate the outcomes of root canals treated with Resilon (Resilon Research LLC, Madison, CT, USA)/Epiphany (Pentron Clinical Technologies, Wallingford, CT, USA) compared to gutta-percha with AH Plus®. The study included 125 patients who had completed root canal treatment between August 2004 and August 2013. The analysis included 80 cases treated with Resilon and 45 with gutta-percha/AH Plus®. The median follow-up period was significantly longer for Resilon (62.5 months) than for gutta-percha (26 months, $p < 0.0001$). Radiographic assessments were performed using the periapical index (PAI), categorizing outcomes into „no lesion present“ (PAI scores of 1 and 2) and „lesion present“ (scores of 3, 4, and 5).

Results: The healing rates revealed that 84.4% of teeth treated with AH Plus® showed no lesions at follow-up, compared to only 52.2% for Resilon ($p=0.0004$). The presence of a preoperative lesion and the type of obturation material were significant predictors of outcomes. Specifically, teeth with Resilon were found to be 5.3 times more likely to have a follow-up lesion compared to those treated with gutta-percha. This study highlights a notable difference in long-term outcomes between the two materials [41].

Table 10:

Summary of the success rates of studies using AH Plus® in obturations, without specifying the technique.

Author	Number of cases	Number of failures of AH Plus®	Follow-up period	Success rate of AH Plus®	Success rate of the competitor	Differences between groups
Barborka, Woodmansey (40)	AH Plus® (N=50), Resilon/Realseal (N=50)	AH Plus®: 6/50	AH Plus®: 6.6 (±1.6) years; Resilon: 5.8 (±1.1) years	88% of the GP cases were considered successful	56% percent of RS cases were classified as successful	Resilon had a 5.7 times higher likelihood of failure compared to AH Plus®/ gutta-percha (p<0.001).
Strange, Tawil (41)	AH Plus®/gutta-percha (N=45) Resilon (N=80)	62.5 months (5.2 years): 7/45	Median for AH Plus®: 26 (IQR=19) months; Median for Resilon= 62.5 (IQR=62) months	Radiographic healing rate for AH Plus®: 84.4%	Radiographic healing rate for Resilon: 52.2%	Healing rate of AH Plus®/ gutta-percha is higher than Resilon (p=0.0004)



Take home message

AH Plus® demonstrated excellent long-term success rates in comparison to Resilon/Realseal.

4 Main outcomes from the selected studies

f. Other factors associated with the success of the treatment and/or post-obturation pain.

Several studies also examined the association between various factors and the outcomes of the included studies. These factors primarily encompassed patient-related factors (e.g., age and sex) as well as tooth-

and treatment-related factors. Among the latter, the most studied factors included tooth position (anterior vs. posterior), arch (maxillary vs. mandibular), presence of pre-operative pain, pulp vitality, sealer extrusion, periapical condition prior to treatment (including the presence of a lesion), obturation technique, and whether the case was a retreat-

ment (**see Table 11**). Of the factors studied, peri-operative pain (7, 12, 26), pulp status (26, 31, 33), and periapical condition before treatment (7, 18, 33, 39, 41) were most strongly associated with the less favourable treatment outcomes. In contrast, the obturation technique did not show a significant association with the treatment outcomes (12, 16, 31, 39).



Take home message

The evaluation of clinical and radiographic success in endodontic primary and secondary treatments plays a crucial role in determining the effectiveness of the procedure in resolving infection, promoting periapical healing, preserving tooth function, and preventing complications. The 22 studies reviewed assessed various clinical parameters, alongside radiographic measurements. The results consistently showed similar clinical and radiographic success rates between AH Plus® and the different sealers used. With AH Plus®, the long-term success rates exceeded 80% in most studies, which supports its excellent sealing performance.

Tooth and treatment								Patient		
Retreat- ment	Obtura- tion tech- nique	Periapical condition before treat- ment	Sealer extrusion	Pulp vitality/ status	Preopera- tive pain	Arch	Tooth Position	Sex	Age	Factors
										Arias, 2013 (7)
										He, 2017 (36)
										Barborka, 2017 (40)
										Pirani, 2018 (33)
										Graunaite, 2018 (13)
										Atav Ates, 2019 (10)
										Fonseca, 2019 (24)
										Strange, 2019 (41)
										Ferreira, 2020 (21)
										Zavattini, 2020 (34)
										Cunha, 2020 (18)
										Tan, 2021 (26)
										Yu, 2021 (12)
										Shim, 2021 (17)
										Drumond, 2021 (11)
										Aslan, 2021 (23)
										Kim, 2022 (16)
										Khandelwal, 2022 (9)
										Martins, 2023 (37)
										Hu, 2023 (35)
										Winkler, 2023 (39)
										Khabiri, 2023 (6)
										Coşar, 2023 (290)
										Radwanski, 2024 (31)
										Yilmaz, 2024 (22)

Table 11:
Factors assessed in the studies in
relation to the treatment outcome.

■ No association observed with pain, analgesic intake, or failure of treatment.
■ Factor associated with pain/treatment failure.
■ Study associated higher analgesic intake with the factor.

5 Conclusion

AH Plus® has been available on the market for 30 years, and this manual aims to review its evidence-based clinical success. The 36 clinical studies included in the review encompassed a total of 3407 patients and 3735 treated teeth. Among the key clinical findings, it is important to highlight the following:

- Mild to moderate post-obturation pain was observed in some of the teeth treated with AH Plus®, which significantly decreased within the first 48 to 72 hours post-obturation, with nearly no pain after 7 days. The use of analgesics was not associated with the use of AH Plus®. There were no differences in comparison to other types of sealers in most studies. Combined, this further reinforced the clinical reliability of AH Plus®.
- The use of AH Plus® resulted in a high treatment success rate regardless of the obturation technique (including single cone obturation) and type of treatment (primary or secondary). In most studies, the long-term success rate exceeded 80%, confirming the performance, reliability, and versatility of AH Plus®.
- The obturation technique did not significantly affect the treatment outcome. However, factors such as preoperative pain and previous periapical condition were associated with treatment outcomes and were considered important prognostic indicators.

In sum, the clinical evidence strongly supports the effectiveness and reliability of AH Plus®, demonstrating its consistent performance across various treatment scenarios.



6 References

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