▶ Review Article ◀

Root Perforation Repair with Calcium Silicate Cements: Part 2- Predictive Factors to the Outcome and Prognosis

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Abstract

The success rates of root perforation repair with calcium silicate cements are 73.3-100% depending on the main prognostic factors. These factors are categorized into preoperative, intraoperative, and postoperative factors in the repair of root perforations using original mineral trioxide aggregate (MTA), which no clinical study in other calcium silicate materials has been found. Radiolucency adjacent to the perforation, location of perforation, size of perforation, probing depth related to the perforation, restorative status before perforation repair, treatment providers, quality of coronal restoration, and post or screw Insertion are among the reporting factors. For decision- making in the treatment, a prognosis of root perforation repair (favorable or unfavorable) has been proposed based on main preoperative factors that affect the success rate of root perforation repair, including (1) the presence of lesions at the root perforation site or periodontal pockets at positions related to the root perforation, (2) the size of root perforation, and (3) the location of the perforation.

Keywords: calcium silicate cement, prognostic factors, root perforation repair, treatment outcome

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1. Introduction

In the previous article (**topics 1 and 2**), basic knowledge and treatment outcomes of root perforation repair with calcium silicate cements have been described. With a follow-up period of at least 12 months, success rates of the root perforation repair are high at 73.3-100% depending on the assessment criteria [1-11]. This article is the second part of the treatment outcomes and prognostic factors of root perforation repair with calcium silicate cements. The objective of this article (part 2) is to describe main prognostic factors to treatment outcomes of root perforation repair with calcium silicate cements. Moreover, the authors have proposed a prognosis based on main preoperative factors that may affect the success rate of root perforation repair, resulting in either a favorable or unfavorable prognosis.

2. Predictive Factors to the Outcome of Root Perforation Repair Using Calcium Silicate Cements

The success rate of root perforation repair ranges between 73.3-100%, and this may be influenced by various related factors [1-11]. In this literature review, these factors are categorized into preoperative, intraoperative, and postoperative factors that may affect the repair of root perforations using a mixed mineral trioxide aggregate (MTA) without additive or accelerator (type 1), which includes only original MTA. No clinical study in other calcium silicate materials has been found. In this context, only the factors with clinically verified evidence of impacting treatment outcomes will be discussed. The details of potential factors to the outcome of root perforation repair are as follows (**Table 1**).

Table 1 Prognostic factors affecting the success rate of root perforation repair using calcium silicate cement (MTA)

Factor type	Factor	Success rate in root perforation repair	Study (year)	Study type
Preoperative factor	Lesion adjacent to the perforation	Absence of lesion > Presence of lesion	Siew et al. (2015) Krupp et al. (2013)	Systematic review and meta-analysis
	Location of perforation	Supra- or sub-crestal level > At crestal level	Pontius et al. (2013)	Retrospective cohort study
			Gorni et al. (2016)	Prospective cohort study
	Size of perforation	Approximately 3 mm or smaller > Larger than 3 mm	Gorni et al. (2016) Gorni et al. (2022)	Prospective cohort studies
	Periodontal probing depth related to perforation	Less than 4 mm > 4 mm or more	Gorni et al. (2016) Gorni et al. (2022)	Prospective cohort studies

Table 1 Prognostic factors affecting the success rate of root perforation repair using calcium silicate cement (MTA) (Continued)

Factor type	Factor	Success rate in root perforation repair	Study (year)	Study type
	Status of coronal restoration before perforation repair	Seal margin > Defective margin (e.g. open margin or caries)	Pontius et al. (2013)	Retrospective cohort study
Intraoperative factor	Treatment providers	Endodontists > General practitioners/ undergraduates	Mente et al. (2014)	Retrospective cohort study
Postoperative factor	Quality of coronal restoration	Seal margin > Defective margin	Pontius et al. (2013)	Retrospective cohort study
	Post or screw insertion	Absence of post or screw > Presence of post or screw	Mente et al. (2014)	Retrospective cohort study

2.1 Preoperative Factors

Lesion Adjacent to the Perforation

-analysis by Siew et al. (2015) [12] and a retrospective cohort study by Krupp et al. (2013) [3] found that the presence of radiolucency at the perforation site significantly reduces the success rate of root perforation repair compared to the absence of radiolucency at the perforation site. The presence of such radiolucency indicates a long-standing perforation combined with an infection from the root canal and/or the perforation site that has not been adequately controlled. This leads to the destruction of surrounding periodontal tissues, creating a pathway between the root canal and the oral cavity, which can easily result in root canal reinfections. Additionally, the repair material may extrude beyond the perforation site, making it more difficult to achieve a tight seal in repairing.

Location of Perforation

Regarding the location of the root perforation, the study by Pontius et al. (2013) [9] found that if the perforation is near the crestal bone level, the success rate of root perforation repair using MTA is significantly reduced. This is because this location is close to the epithelial attachment, increasing the likelihood of creating a pathway between the root canal and the oral cavity. This pathway can lead to contamination of the root canal by oral pathogens, making it difficult to control the infection before repair. Furthermore, if the repair material comes into contact with oral fluids in the area of the perforation and that material has a slow setting time, such as MTA, the material may partially dissolve, affecting the seal. Any perforations located below the crestal bone level, where there is no connection to the oral cavity, tend to have a higher success rate in root perforation repair.

The study by Gorni et al. (2016), which followed up on cases where healing occurred within the first 1-2 years after root perforation repair and continued follow-up until 8 years, found that teeth that had initially healed completely later developed new lesions at the perforation site [1]. When analyzing the location of the perforation, it was found that perforations at the intermediate or apical levels of the root were more likely to result in this long-term repair failure compared to those at the coronal level. This finding partly differs from Pontius et al. (2013) [9] as it examines the factors that contribute to recurrence of disease in teeth that initially healed after root perforation repair. Additionally, the study only considered the perforations within the root segments, so the perforations at the crestal bone or supra-crestal level was not included in their analysis.

Size of Perforation

The studies by Gorni et al. (2016, 2022) [1, 2] found that teeth with a root perforation size greater than 3 mm have a significantly higher rate of recurrent disease after complete healing during the 8-year and 14-year follow-up periods compared to teeth with a perforation size of 3 mm or less. This may be because a perforation larger than 3 mm reduces the amount of root dentin, leading to a thinning and weakening in the perforation area, which increases the likelihood of root fracture over long-term use.

In terms of measuring the size of the perforation, Mente et al. (2014) [7] used a periodontal probe to estimate the diameter under a dental operating microscope, categorizing the perforation size into three levels: less than 1 mm, 1–3 mm, and greater than 3 mm. Later, Gorni et al. (2016) [1] measured the perforation size either clinically or radiographically. If the perforation was visible clinically, the size was estimated using a periodontal probe under a dental operating microscope. If the perforation was not clearly visible, the size was estimated from radiographs by comparing the perforation size to the root width or length, with the same three categories of perforation size being used.

Periodontal Probing Depth Related to the Perforation

The studies by Gorni et al. (2016, 2022) [1, 2] found that teeth with a periodontal probing depth of less than 4 mm in the area corresponding to the root perforation have a significantly higher success rate in treatment compared to teeth with a probing depth of 4 mm or more. A probing depth of 4 mm or more indicates inflammation and destruction of the periodontal tissues and alveolar bone at that site, making it more likely for the repair material to extrude beyond the perforation and difficult to achieve a tight seal. This can delay the healing process compared to cases where the repair material does not extend beyond the perforated root area. Moreover, according to the study by Shie et al. (2009) [13], the presence of periodontal inflammation creates an acidic environment at the perforation repair site, which can interfere with the setting and sealing of the repair material (e.g., MTA), potentially creating small micro-gaps at the repair margins. These micro-gaps can allow bacteria to re-enter the root canal, leading to reinfection and potential failure of the root perforation repair.

Status of Coronal Restoration before Perforation Repair

The study by Pontius et al. (2013) [9] found that if the restorative status of the teeth before root perforation repair is considered acceptable based on radiographic evaluation- the margins of restorations are well-sealed, no leakage, and no recurrent decay, their success rates of root perforation repair are significantly higher than in the teeth where the quality of the restorations is unacceptable. This is because a good-quality restoration helps to create a sealed environment, preventing oral bacteria from entering the root canal during treatment, thereby contributing to the success of the repair.

In summary, current studies indicate that factors affecting the healed rate of periapical lesions in root perforation repaired with a calcium silicate material (i.e. MTA) include the presence of lesions at the perforation site, the location of the perforation, the size of perforation, the periodontal probing depth, and the quality of the coronal restoration before repair. Other clinical factors, such as the tooth's position in the jaw, clinical symptoms before treatment, the condition of the pulp (pulpitis vs. pulp necrosis), or the duration between the perforation and repair, do not affect the success rate of root perforation repair [1-12]. At long-term period, the factors that influence the recurrent rate of peri-radicular disease of root perforation repaired with the calcium silicate material include the size of the perforation and the periodontal probing depth.

2.2 Intraoperative Factors

Treatment Providers

The study by Mente et al. (2014) [7] found that the experience of the dental practitioners providing the treatment affects the success of root perforation repair. In particular, endodontic specialists have a significantly higher success rate in repairing root perforations compared to general dentists and dental students. This may be due to the need for experience in diagnosing root perforations, controlling infections, and using appropriate materials for repairing root perforations to ensure the most effective repair.

For other factors during treatment, such as the number of treatment sessions, cleaning and shaping techniques, and root-filling techniques, these were found not to significantly impact the success of root perforation repair. This is because if inflammation and infection are well-controlled prior to repair, by using an effective root canal irrigant such as sodium hypochlorite and placing medication in the root canal along with proper root canal obturation, the treatment outcomes will not differ significantly regarding these factors [3-7, 9-11].

2.3 Postoperative Factors

Quality of Coronal Restoration

The study by Mente et al. (2014) [7] found that during the follow-up period of 12-65 months, the success rate of root perforation repair was high regardless of the quality of the restoration. However, this may be because the follow-up period was short, and therefore, no fractures were observed in the restored teeth, leading to similar success rates during that time.

In contrast, a study by Pontius et al. (2013) [9], which had a longer follow-up period of 116 months, found that if the quality of the coronal restoration was good, without leakage or recurrent caries, the success rate of root perforation repair was significantly higher than in teeth with poor-quality coronal restorations. This is consistent with other studies that confirm the quality of the restorations significantly affects endodontic treatment outcomes.

Post or Screw Insertion

The study by Mente et al. (2014) [7] found that the success rate of treatment decreased when a post was placed in teeth with root perforation repair. This may be because such teeth with perforations often have significant tooth structure loss or are used as abutments supporting fixed or removable prostheses. Additionally, the preparation of the canal for the post reduces the amount of tooth structure in the root (that already weaken by the perforations), which affects the tooth strength particularly when subjected to force. This could lead to failures by root fractures in teeth that have had a post placed in the perforated roots after the perforation repair.

3. Prognosis of Teeth with Root Perforation Repair using Calcium Silicate Cements

From current clinical evidences, an update prognosis has been proposed based on main preoperative factors that may affect the success rate of root perforation repair, resulting in either a favorable or unfavorable prognosis (**Table 2**). These factors include the presence of lesions at the root perforation site or periodontal pockets at positions related to the root perforation, which lead to an unfavorable prognosis. Compared to the previous prognosis by Fuss & Trope [14] or American Association of Endodontists (AAE) [15], this factor (a presence of lesion or periodontal pocket) is related to 'time to repair perforation' (immediate or delay) that reflects the degree of root canal infection particularly at the perforation. The other two factors are as same as those proposed by Fuss & Trope [14] or American Association of Endodontists (AAE) [15]- the size and the location of the root perforation. With a large perforation (> 3mm) and/or at the alveolar bone crest level, the prognosis will be unfavorable. These preoperative factors (size and location) have been already occurred and cannot be controlled.

Table 2 Main preoperative factors on prognosis (favorable or unfavorable) of root perforation repair using calcium silicate cement

Factors	Favorable	Unfavorable*
Lesion or pocket depth ≥ 4 mm at perforation	Absent	Present
Size of perforation	Small to moderate (≤ 3mm)	Large (> 3mm)
Location of perforation	Supra- or sub-crestal level	Crestal level

*Higher possibility of treatment failure, characterized by the emergence of new lesions at the site of root perforation and/or the presence of signs & symptoms of root fracture. An unfavorable outcome in root perforation repair is most commonly observed as a long-term failure after a follow-up period of 2-3 years or longer [1, 2].

However, the first preoperative factor (lesion and/or pocket) that reflects the root canal infection can be managed before repairing root perforations with calcium silicate cement materials. It is important to control inflammation and infection in root canals and at perforations before repairing, especially in cases with bone destruction or periodontal pockets associated with the root perforation site. By the lesions or pocket depth at the perforations communicating with the oral cavity, maintaining disinfection before repair and sealing of repair material are more difficult, reducing treatment success rates.

Conclusion

From clinical studies, several factors affect the treatment outcome of root perforation repairs. Correct diagnosis & proper management by endodontists and continuous long-term follow-up can improve the chances of successful root perforation repair. Moreover, restorative dentists also play a crucial role in the success of root perforation repair by placing of coronal restoration to provide coronal seal and protect remaining tooth structure, and avoiding the use of dental posts in the perforated roots. Although many studies confirm the success rates and factors influencing the success of root perforation repair with calcium silicate cement materials, almost all studies use non-accelerated, mixed MTA materials (type 1). Therefore, further studies on other types of calcium silicate cement materials are needed to assess the success of the treatment and to identify factors that may affect the success and prognosis.

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