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Prognosis of Fragment Reattachment in Anterior Crown Fractures: A Retrospective Study

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ABSTRACT

Objective: Although several studies have compared fragment attachment with resin build-ups in anterior crown fractures, none have specifically investigated the outcome of reattached fragments. This retrospective study aimed to evaluate long-term outcomes of fragment reattachment in anterior crown fractures and determine the prognostic affecting their success.

Materials and Methods: We retrospectively analyzed clinical records of patients who underwent fragment reattachment for crown fractures in anterior teeth (maxillary and mandibular central and lateral incisors) between 2008 and 2023. All procedures were performed by experienced professors and residents following a standardized protocol. Kaplan–Meier survival curves and Cox proportional hazards regression analyses were performed to evaluate fragment retention outcomes and identify potential prognostic factors.

Results: Among 75 anterior crown fractures, the estimated fragment retention rates were 83.7% at 2 years, 75.2% at 5 years, and 56.4% at 10 years. Multivariate Cox regression analyses identified patient age and extent of crown fracture as significant factors affecting outcomes. The 5-year estimated fragment retention rates were 82.8% and 67.0% for uncomplicated and complicated crown fractures, respectively.

Conclusions: Fragment reattachment remains a viable treatment option for anterior crown fractures. Treatment success decreased with patient age, and complicated crown fractures demonstrated lower retention rates than uncomplicated ones.

Clinical Significance: Fragment reattachment can provide predictable outcomes in anterior crown fractures when cases are carefully selected, particularly considering the patient's age and the type of crown fracture.

1 | Introduction

Crown fractures are the most common traumatic injuries of permanent anterior teeth [1, 2]. Due to their position, anterior teeth are often subjected to external forces [3], necessitating restorations that are aesthetically pleasing, functional, and time-efficient [4]. According to the current International Association of Dental Traumatology guidelines, both uncomplicated and complicated crown fractures can be managed either by direct composite restoration or reattaching the fractured fragment [5]. The main challenge for clinicians is restoring the natural appearance of a fractured tooth, including its shape, size, color, opacity, translucency, fluorescence, and opalescence [6]. These challenges can be overcome by composite resin build-up using various shades and types of resins. However, this method requires extended clinical time, is technique-sensitive, and creates difficulties in obtaining an acceptable shape, surface texture, and translucency [7, 8].

Fragment reattachment has become increasingly popular due to advancements in dentin bonding agents. Since the introduction of crown fragment reattachment in 1964 [9], adhesive techniques have significantly evolved, resulting in more preventive and favorable outcomes. Fragment reattachment is a viable treatment option for crown fractures when an intact fragment is available [10], offering several advantages such as restoring the tooth to its original anatomical structure, color, and function in a minimal amount of time [6, 11]. Furthermore, unlike other types of restorations, the incisal edges of reattached fragments exhibit wear patterns similar to those observed in the adjacent natural teeth [12]. It has been reported that when a tooth fragment is preserved following crown fractures, the optimal treatment approach is reattachment [13].

Studies have reported that the primary cause of fragment loss is either new dental trauma or non-physiological use of the restored tooth [7]. Therefore, most concerns regarding reattachment techniques have been directed toward the fracture strength of restored teeth [14, 15]. Laboratory tests conducted under controlled conditions can only evaluate the resistance of a material to a single factor, lacking exposure to various mechanical, physical, and chemical influences present in the oral environment [16]. Consequently, the clinical outcomes often differ significantly. Thus, laboratory investigations cannot be directly applied in clinical settings without limitations [17]. Although several clinical studies have investigated the outcomes of fragment attachment compared with composite resin build-up in anterior crown fractures [13, 18, 19], none have separately investigated the potential prognostic factors for the retention of reattached fragments. Moreover, clinical studies comparing the retention rates of fragment reattachment between uncomplicated and complicated crown fractures are limited [13]. Therefore, it is important to gather additional fundamental clinical data and expected outcomes associated with fragment reattachment.

Consequently, this retrospective study aimed to evaluate the outcome of fragment reattachment and determine the prognostic factors affecting the outcome. The null hypothesis was that there are no significant differences in the retention of reattachment fragments according to various influencing factors.

2 | Materials and Methods

2.1 | Study Population

This retrospective study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the Yonsei University Dental Hospital Institutional Review Board (approval no. 2-2023-0063). The study included patients treated for dental trauma at the Department of Conservative Dentistry, Yonsei University Dental Hospital between January 2008 and December 2023. All digital and paper-based dental records of patients who underwent fragment reattachment after traumatic dental injury were reviewed by a single investigator to ensure consistent data collection. Patients diagnosed with "uncomplicated crown fracture" or "complicated crown fracture" in the permanent anterior teeth (maxillary and mandibular central and lateral incisors) were included.

The exclusion criteria were as follows:

1. Inadequate documentation or follow-up period < 1 year.
2. Previous root canal-treated tooth.
3. Crown fracture due to dental caries.
4. Tooth with crown-root fracture.
5. Tooth with displacement due to luxation injury (e.g., extrusive luxation).
6. Tooth with a developmental disorder (e.g., hypomineralization, hypoplasia).
7. Temporary reattachment before definitive treatment.
8. Severely damaged tooth without the possibility of preservation.
9. Cases with non-traumatic tooth loss due to periodontal problems.

Cases that failed before completing 1-year follow-up after reattachment were included in the study and recorded as failures.

2.2 | Diagnostic and Treatment Principles

All clinical procedures followed a standardized protocol based on the International Association for Dental Traumatology (IADT) guidelines for the management of traumatic dental injuries [5, 20, 21], and were performed by experienced professors and residents at the Department of Conservative Dentistry, Yonsei University Dental Hospital. Before treatment initiation, diagnoses were made based on clinical and radiographic examinations. A comprehensive evaluation of dental hard tissues, pulpal status, periodontal health, and alveolar bone was conducted during initial and subsequent visits. Reattachment was considered viable when the coronal fragment was intact, regardless of factors such as pulp exposure or defect size. The extent of crown fracture was categorized as complicated if it involved pulp exposure and as uncomplicated if there was no pulp exposure. When pulp exposure was present, the treatment choice depended on the extent of exposure. Direct pulp capping with an aqueous calcium hydroxide suspension (Dycal; Dentsply Sirona, York, PA) was performed for exposures with a diameter of 0.5 mm or less. For larger exposures, partial pulpotomy with calcium silicate cement (ProRoot MTA; Dentsply Sirona, York, PA, or retroMTA; bioMTA, Seoul, Republic of Korea) was performed. Root canal therapy was performed in patients with significant pulpal exposure or necrotic pulp. Post-placement was considered in cases of extensive loss of coronal tooth structure. Patients who were diagnosed with irreversible pulpitis after pulp capping or partial pulpotomy also underwent root canal therapy after fragment reattachment.

The fragment was examined for marginal adaptation to the fractured tooth surface to determine its suitability for reattachment. When adequate adaptation was confirmed, the fragment was rehydrated in distilled water for 30 min before the reattachment procedure to optimize bond strength between the fragment and the remaining tooth structure. For fragments of substantial size or those containing pulp remnants, an internal groove

was prepared to enhance retention. External beveling was performed either before or after the reattachment procedure to optimize the esthetic outcome and strengthen the bonding interface. Enamel of both the fragment and the remaining tooth structure were etched with 37% phosphoric acid for 20 s. The adhesive was then applied according to the manufacturer's instructions using either a two-step self-etching adhesive (Clearfil SE Bond; Kuraray, Osaka, Japan) or a universal adhesive (All Bond Universal; Bisco, Schaumburg, IL). After light curing of the adhesive, a flowable composite (Metafil flo α; Sun Medical, Shiga, Japan) was applied to both surfaces to ensure complete adaptation between the fragment and the tooth. The fragment was precisely repositioned, and excess composite material was carefully removed with an explorer. Each surface was light-cured for 20 s (buccal and palatal surfaces, respectively) using an LED curing light.

All patients were scheduled for regular recall visits at 1, 3, 6 months, 1 year, and annually thereafter to monitor the treatment outcome. At each recall visit, the treated teeth were evaluated both radiographically and clinically. Clinical examination included assessment of fragment retention, marginal adaptation, and color match. When the reattached fragment remained intact with satisfactory adaptation, no additional treatment was required. Surface polishing was performed if any discoloration or surface roughness was observed.

2.3 | Analysis of the Patient Records

The following data were collected: patient characteristics (sex and age); information about the traumatized teeth (tooth number, date of the dental trauma, and extent of crown fracture [complicated or uncomplicated]); details of the corresponding treatment (type of pulp treatment [pulp capping, pulpotomy, or root canal treatment] and clinician's experience). Cases were excluded if documentation was insufficient or if the minimum required information could not be retrieved from the patient's records. Reattachments that remained in place without any additional intervention until the date of censoring (last review) were classified as "survived." Detachment of the fragment was defined as a "failure."

2.4 | Statistical Analysis

All statistical analyses were performed by using SPSS 27 software (IBM Corp, Somers, NY) and R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). The level of significance was set at 0.05 with 95% confidence interval (CI). Associations between fragment retention and independent variables were assessed using a cross-tabulation analysis. A survival analysis was conducted to assess the prognosis of fragment reattachment over time. Success rates were estimated using the Kaplan–Meier method. Subsequently, potential prognostic factors influencing the success of fragment reattachment were analyzed. All variables were subjected to multivariate Cox proportional hazards regression analysis, followed by stepwise regression using the backward elimination method. Hazard ratios (HRs) and 95% CIs were calculated for variables significantly associated with failure.

3 | Results

A total of 68 patients with 75 crown fractures were included in the study (39 males and 29 females; age range: 8–86 years, mean age: 32.7 years). The observation period ranged from 0 to 14.7 years (mean: 2.3 ± 3.02 years). The characteristics and distribution of all cases are summarized in Table 1. The most frequently fractured teeth were the upper central incisors ($N = 64$), followed by the upper lateral incisors ($N = 8$). Lower incisors were the least frequently observed ($N = 3$).

The estimated fragment retention rates were 83.7% (95% CI: 73.7%–95.1%) after 2 years, 75.2% (95% CI: 61.6%–91.9%) after 5 years, and 56.4% (95% CI: 35.6%–89.3%) after 10 years. Table 2 presents the potential risk factors from the multivariate analysis. Multivariate Cox regression analyses revealed that age and extent of crown fracture were significant factors affecting treatment outcomes. As patients aged, the probability of failure significantly increased (HR = 1.049; $p = 0.002$). Complicated crown fractures had a significantly higher probability of failure than uncomplicated crown fractures (HR = 5.945; $p = 0.025$). For uncomplicated crown fractures, the estimated retention rates were 96.6% (95% CI: 90.1%–100%) after 2 years and 82.8% (95% CI: 60.7%–100%) after 5 years, whereas for complicated crown fractures, the estimated retention rates were 72.5% (95% CI: 56.6%–92.9%) after 2 years and 67.0% (95% CI: 49.9%–89.8%) after 5 years. Treatments after fragment detachment were as follows: reattachment ($N = 5$) when the detached fragment was intact, crown restoration ($N = 5$) when the fragment was not feasible for reattachment, and extraction ($N = 2$) when an additional fracture occurred during detachment. Figure 1a presents the Kaplan–Meier survival curves for all fragment reattachment cases with the number at risk, while Figure 1b presents the Kaplan–Meier survival curves in relation to pulp exposure. Figure 2 shows a representative successful case that survived for 11 years after fragment reattachment, while Figure 3 demonstrates a failed reattachment after 2 years.

4 | Discussion

This retrospective study provides valuable information on the outcome and prognostic factors for fragment reattachment of permanent anterior teeth with crown fractures following traumatic dental injuries. To the best of our knowledge, no previous studies have individually investigated the potential prognostic factors for the retention of reattached fragments. The estimated fragment retention rates were 83.7% (95% CI: 73.7%–95.1%) after 2 years, decreasing to 75.2% (95% CI: 61.6%–91.9%) after 5 years and 56.4% (95% CI: 35.6%–89.3%) after 10 years (Figure 1a). Our results demonstrated that the extent of crown fracture and patient age were significantly associated with the outcome of fragment reattachments (Table 2, Figure 1b). These rates are comparable to those reported by a previous study which demonstrated an estimated fragment retention rate of 74.6% after 2 years [13]. However, another study reported an estimated fragment retention rate of 42.9% after 2 years [18]. The variation in reported retention rates across studies might be attributed to differences in sample size, patient selection criteria, and study methodology, highlighting the need for well-structured prospective studies.

TABLE 1 | Characteristics and distribution of fragment reattachment cases.

	Retention *N* (%)	Failure *N* (%)	*p**
Total	63 (84%)	12 (16%)	
Age group			0.022
< 10	4	2	
10–19	25	2	
20–29	15	2	
30–39	10	0	
40–49	9	6	
Gender			0.338
Male	35 (79.5%)	9 (20.5%)	
Female	28 (90.3%)	3 (9.7%)	
Location			0.772
Upper central incisor	54 (84.3%)	10 (15.7%)	
Upper lateral incisor	6 (75.0%)	2 (25.0%)	
Lower central incisor	2 (100.0%)	0	
Lower lateral incisor	1 (100.0%)	0	
Extent of crown fracture			0.060
Uncomplicated crown fracture	30 (93.8%)	2 (6.3%)	
Complicated crown fracture	33 (76.7%)	10 (23.3%)	
Type of pulp treatment			0.228
No treatment	25 (92.6%)	2 (7.4%)	
Pulp capping	6 (75.0%)	2 (25.0%)	
Pulpotomy	8 (80.0%)	2 (20.0%)	
Root canal treatment	24 (80.0%)	6 (20.0%)	
Clinician's experience			0.719
Resident	47 (82.5%)	10 (17.5%)	
Professor	16 (88.9%)	2 (11.1%)	

*The *p* from chi-squared test or Fisher's exact test.

While maxillary central incisors are most commonly affected by dental trauma due to their anatomical position, our study included both central and lateral incisors in the maxillary and mandibular arch to comprehensively evaluate fragment reattachment outcomes. The distribution of tooth types in our study sample (Table 1) reflects the varying prevalence of crown fractures among anterior teeth in clinical practice. Although focusing on a single tooth type might have reduced potential variables, such as differences in crown size, root length, and occlusal forces, our inclusive approach provides more generalizable findings applicable to routine clinical scenarios. However, this diversity in tooth types should be considered when interpreting our results, as anatomical and functional differences between tooth types might influence fragment retention outcomes.

Teeth with uncomplicated crown fractures had a higher retention rate for reattached fragments than those with complicated crown fractures (Table 2). Multivariate Cox proportional hazard regression analysis indicated that the adjusted HR for teeth with complicated crown fractures was 5.945 times higher than that for teeth with uncomplicated crown fractures. This finding aligns with a previous retrospective study by Bissinger et al. [13], which attributed the higher fragment loss rate in complicated crown fractures to the larger fragment sizes associated with more severe fractures, leading to a higher likelihood of detachment. According to a systematic review, the fragment loss rate is higher for complicated crown fractures than for uncomplicated fractures [22]. The authors attributed this to the increased risk of moisture contamination at the bonding site, especially when oblique fracture lines end in the gingival sulcus. In addition, teeth with complicated

TABLE 2 | Final model from the multivariate Cox regression analysis.

	Hazard ratio	95% CI	Standard error	*p*
Age	1.049	1.018–1.080	0.701	0.002*
Extent of crown fracture				
Uncomplicated crown fracture				
Complicated crown fracture	5.945	1.246–28.372	0.797	0.025*
Sex				
Female				
Male	3.665	0.928–14.470	0.701	0.064

*Statistically significant ($p < 0.05$).

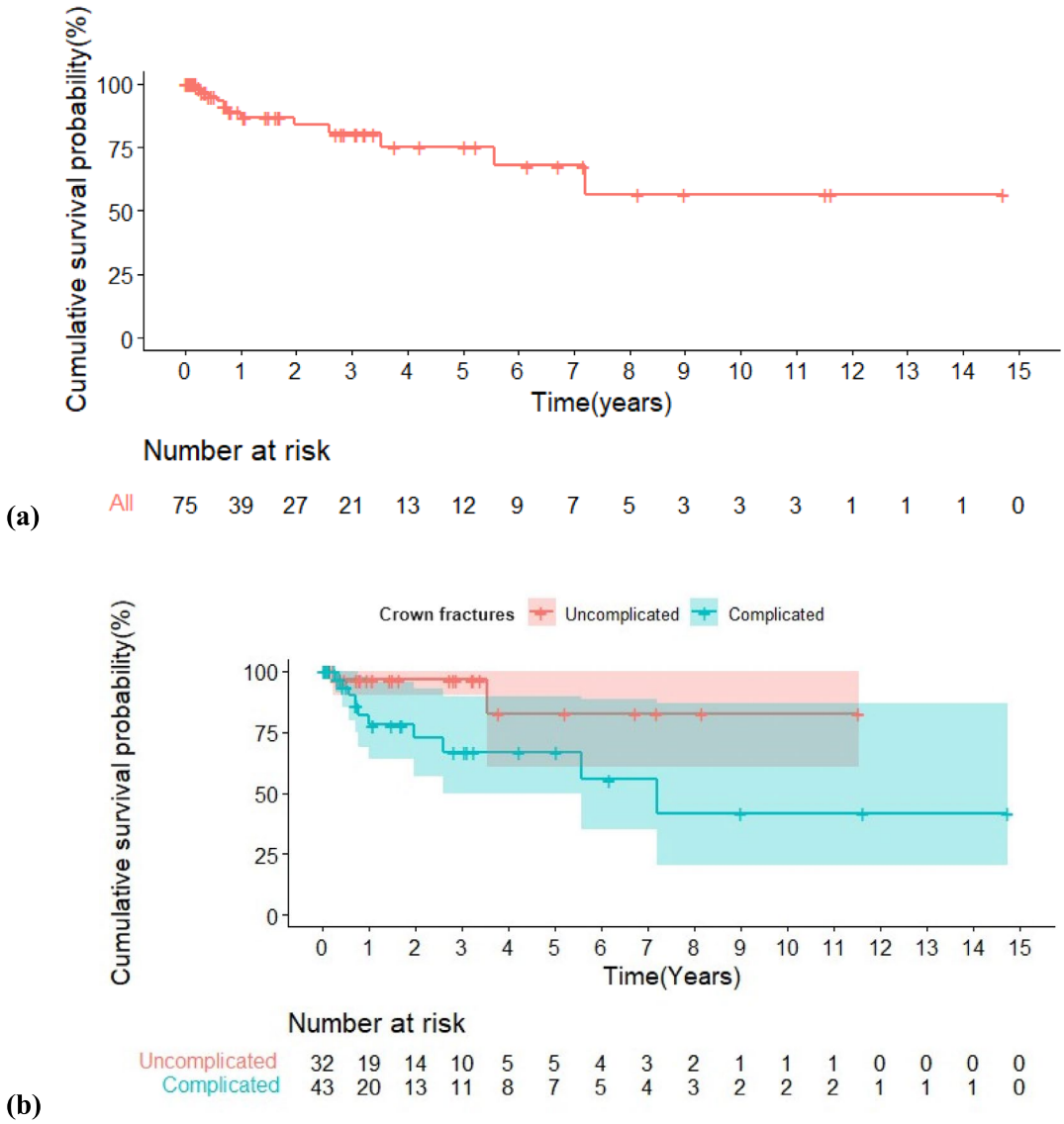

FIGURE 1 | (a) Kaplan–Meier survival curve for all fragment reattachment cases. (b) Kaplan–Meier survival curve in relation to the extent of crown fracture.

crown fractures inevitably produce longer arm effects. An increase in the lever arm length may lead to a reduction in fracture resistance [23].

Several in vitro studies have revealed that age does not affect the bond strength of adhesives to dentin [24–27]. However, contrary to previous studies [13, 18, 19], this study found that

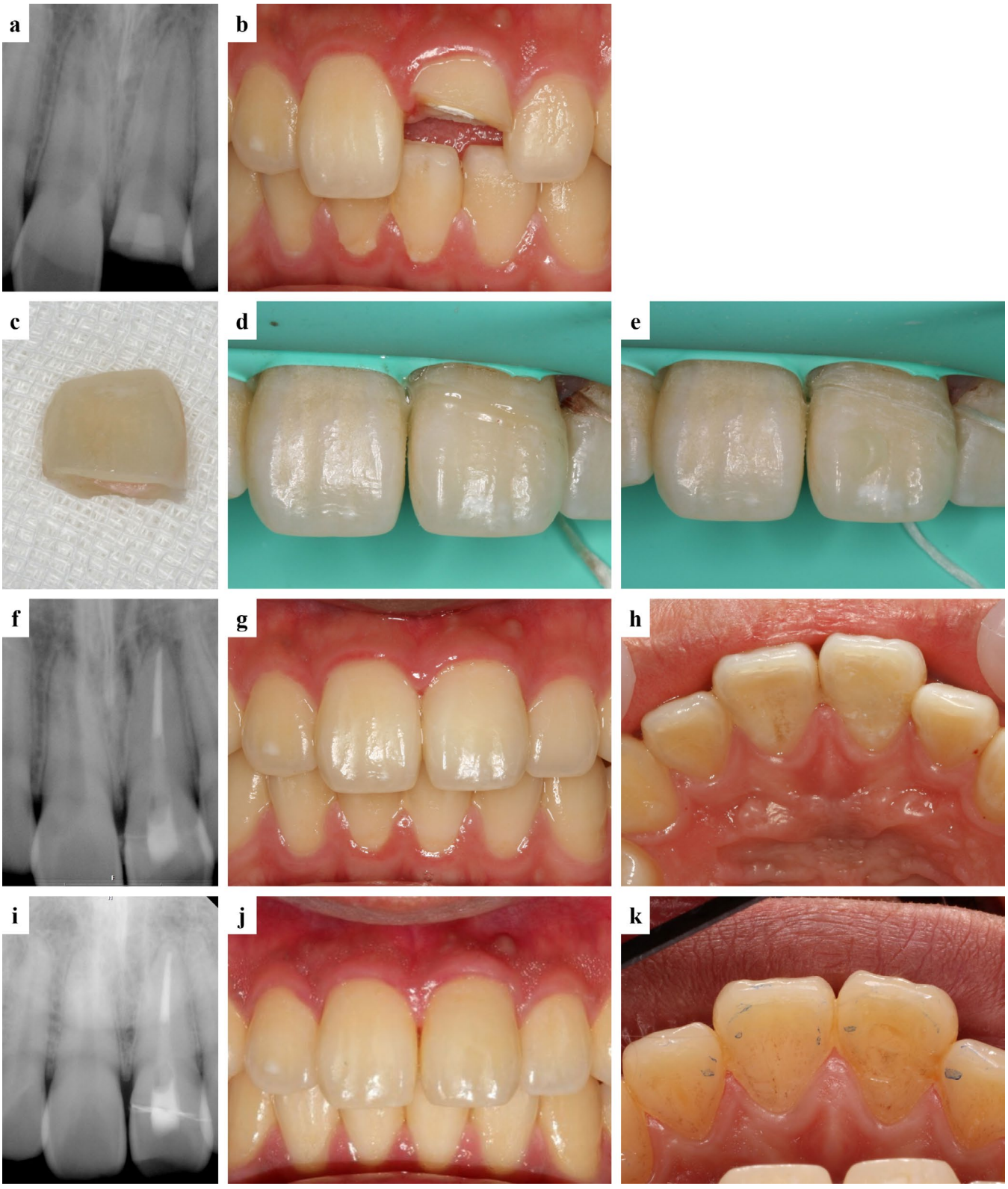

FIGURE 2 | A representative case for successful fragment reattachment. (a, b) Periapical radiograph and intraoral photograph of tooth #21 from a 21-year-old male patient with a complicated crown fracture. Root canal treatment had been initiated. (c–e) The fractured crown fragment was adhesively reattached using a flowable composite, followed by the external bevel preparation technique. Following the root canal treatment, a fiber post was placed, and the access cavity and the bevel were filled with composite resin. (f–h) One month after fragment reattachment, the patient had no abnormal signs or symptoms. (i–k) Eleven years after fragment reattachment. The reattached fragment remained well in situ without any complications such as discoloration, fracture, or secondary dental caries.

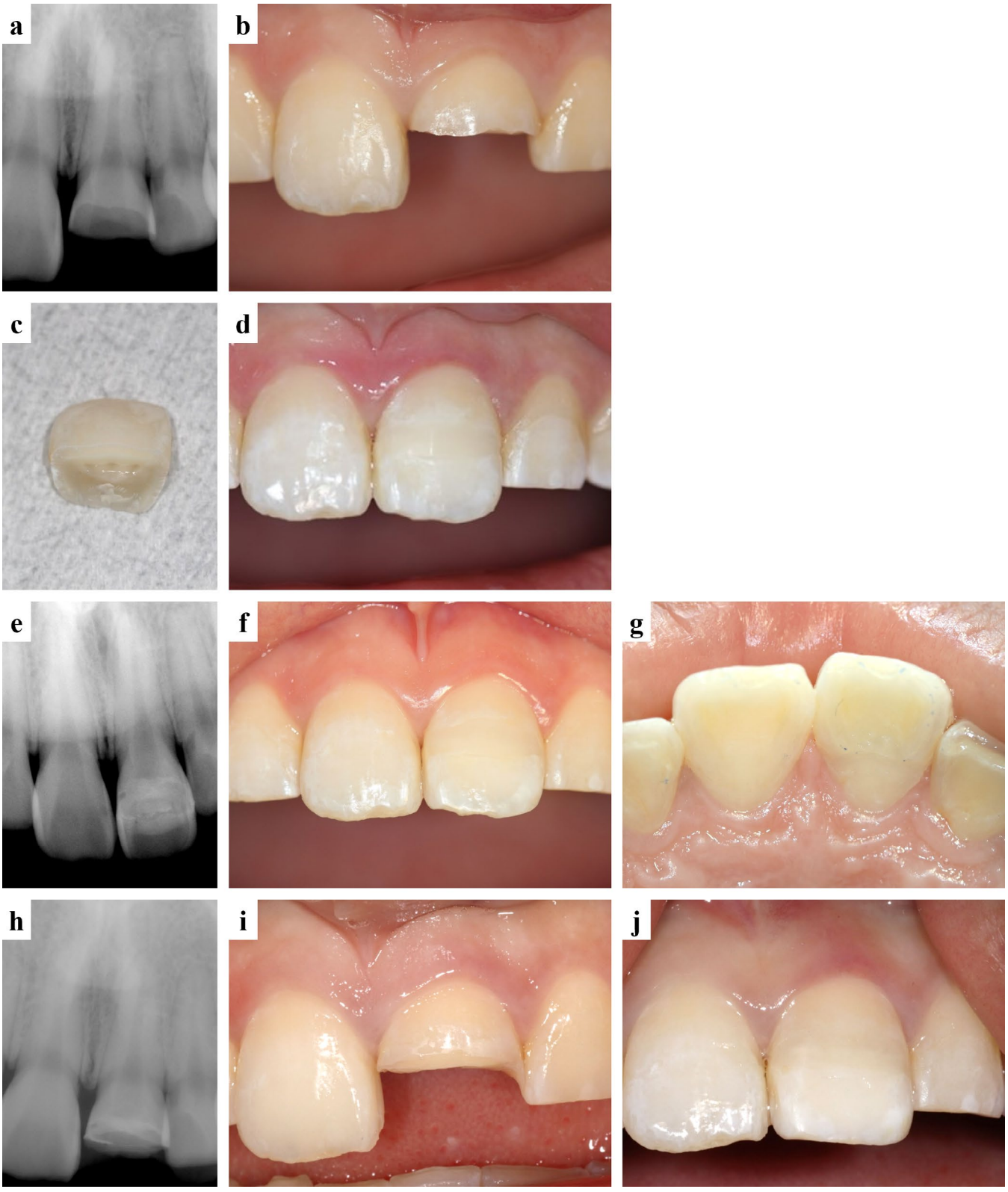

FIGURE 3 | A representative case of failed fragment reattachment. (a, b) Periapical radiograph and intraoral photograph of tooth #21 from a 17-year-old female patient with a complicated crown fracture. A 2-mm depth of partial pulpotomy was performed using calcium silicate cement (RetroMTA; BioMTA, Seoul, Republic of Korea). (c, d) The fractured crown fragment was adhesively reattached using a flowable composite with an external bevel preparation technique. (e–g) A week after fragment reattachment, the patient had no abnormal signs or symptoms. (h, i) After 2 years from fragment reattachment, detachment occurred. (j) Since the detached fragment remained intact, it was reattached with a wider bevel and deeper internal groove preparation.

patient age significantly affected treatment outcomes, with older patients exhibiting a higher susceptibility to treatment failure. It was shown that for each 1-year increase in a patient's age, there was a corresponding 4.9% increase in the risk of failure. The higher susceptibility of older patients to tooth fractures may be attributed to factors such as an increase in both the number and size of restorations and a higher prevalence of endodontically treated teeth [28]. Furthermore, the loss of teeth throughout life can increase the load per tooth as the chewing surface area is reduced [29]. However, these results should be interpreted with caution due to the inherent limitations of this retrospective study.

The location of the tooth was not considered a significant factor related to the outcome of the reattached fragments. As mentioned in the Introduction, the main causes of fragment loss are new dental trauma or non-physiological use of the restored tooth [7] with maxillary central incisors being the most frequently affected teeth [6, 30]. Considering these previous studies, the differences in sample sizes between the central and lateral incisor groups may have influenced this result, which might have been different if the sample sizes had been similar.

In this study, 50% of failures were diagnosed within the first year of reattachment, increasing to 66.7% after 2 years. This finding aligns with two other clinical studies which reported 66.6% and 77.7% of restorative loss diagnosed within the first year of reattachment, increasing to 71.4% and 94.4% after 2 years, respectively [13, 18]. One study that assessed the longevity of reattachments and composite restorations reported that 84.8% of the complications (loss of restoration) occurred within the first 2 years after the accident [19]. Another relevant study presented similar results, indicating that 71.4% of restorative failures were diagnosed within 2 years [18]. These results, combined with our current findings, highlight the importance of short-term follow-up within the first few years after the fragment reattachment procedure.

Numerous studies have investigated the ideal technique for adhesive reattachment of fractured crowns. Techniques involving different preparations, adhesive strategies, and materials have been extensively explored in laboratory studies [7, 10, 31–33]. A systematic review of tooth reattachment methods suggested that a technique involving reattachment with additional preparation using an adhesive system along with an intermediate composite effectively restores the strength loss in fractured teeth [22]. Based on these observations, simple reattachment is not recommended. Therefore, in line with the results of this study, dentists should improve their reattachment techniques. This can be achieved by adhering to the recommended bonding method and following the steps suggested in previous studies [14, 17], such as preparing grooves, employing over-contouring techniques, chamfering, and beveling, to improve treatment outcomes. However, due to insufficient documentation, it was not feasible to compare the various techniques for reattaching fragments in this study. Limited evidence suggests that post-placement could enhance fracture strength [34]; however, clinical studies investigating long-term outcomes remain scarce. In our study, among 30 cases of fragment reattachment following root canal treatment, 18 cases without post-placement resulted in 2 failures (88.9% success), while 12 cases with post-placement showed 4 failures (66.7% success). Although the sample size was insufficient for statistical comparison, our observations suggest that cases with post-placement may be associated with more unfavorable clinical fracture patterns.

The inherent limitation of our study was its retrospective nature. We relied on records that were not originally intended for data collection and analysis, which resulted in the absence of certain data. Furthermore, ~10 different practitioners treated patients at different intervals, introducing both advantages and limitations to our study. While the participation of multiple practitioners provided diverse clinical perspectives and enhanced the generalizability of our findings through a broader representation of clinical treatment variability, it also potentially introduced inter-operator variability in treatment techniques. To minimize this limitation, we implemented a standardized protocol based on the IADT guidelines within our specialized department. However, variations in diagnostic and treatment approaches may have still occurred due to differences in clinical experience and skills among practitioners, which should be considered when interpreting our results.

The retrospective design of this study limited our ability to analyze several potentially significant factors affecting fragment retention outcomes, such as dietary habits, chewing patterns, occlusal forces, and skeletal patterns, as these were not consistently documented across all patients. Additionally, it was not possible to determine the specific causes of fragment detachment, such as maladaptation of the fragments, premature occlusal contacts, parafunctional habits, or technical aspects of the clinical procedures. Future prospective studies should consider incorporating these factors to better understand their impact on fragment reattachment success.

Despite these limitations, our study has several strengths. The retrospective design allowed for a prolonged observation period, potentially extending up to 10 years. Furthermore, all patients included in this study were treated in the 21st century, indicating that treatment decisions were influenced by contemporary clinical guidelines using modern dental adhesive systems [20, 21, 35]. To the best of our knowledge, this is the first study to separately investigate the potential prognostic factors for the outcome of reattached fragments. Our comprehensive statistical analysis enabled us to evaluate how different factors affect the longevity of reattached fragments. Therefore, this retrospective study offers valuable insights for predicting the outcomes of fragment reattachment following crown fractures.

5 | Conclusions

Within the limitations of this retrospective study, the results indicate that fragment reattachment remains a viable treatment option for anterior crown fractures. The null hypothesis was rejected as age and extent of crown fracture significantly influenced fragment retention outcomes, with older patients and complicated crown fractures showing higher failure rates. Additional reinforcement measures should be considered for these high-risk cases. Furthermore, since more than half of the failures occurred within the first 2 years after trauma, intensive monitoring during this period is essential for optimal outcomes.

Author Contributions

Lisu Sung: methodology, investigation, analysis, writing – original draft and revised manuscript. **Hyemin Ku:** methodology, analysis, visualization, writing – original draft, review, and editing. **Yooseok Shin:** analysis, visualization, review, and editing. **Salma Swaid:** analysis, writing – revised manuscript, review, and editing. **Dohyun Kim:** conceptualization, methodology, resources, visualization, writing, review, and editing. **Byoung-Duck Roh:** conceptualization, methodology, resources, visualization, writing, review, and editing.

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Ethics Statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Approval for this project was obtained from the Yonsei University Dental Hospital Institutional Review Board (approval no. 2-2023-0063). For this type of study, formal consent is not required.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

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

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