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Case Report

Periodontal status of teeth with crown–root fractures: results two years after adhesive fragment reattachment

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Abstract
Aim: This series of case reports evaluated the impact of adhesive crown–root fragment reattachment in periodontally healthy teeth suffering from crown–root fractures on various parameters of periodontal health over a time course of 2 years.
Material and Methods: A total of 20 teeth with crown–root fractures in 18 periodontally healthy subjects were evaluated. After open-flap access, crown–root fragments were adhesively reattached to the root stub. In all cases, the vertical difference between the alveolar bone crest and the fracture line was $\leqslant 1$ mm, i.e. violating the biological width. Subsequently, clinical attachment level (CAL), probing pocket depth (PPD), bleeding on probing (BoP) and gingival index (GI) scores were recorded at 6, 12 and 24 months postoperatively for the restored teeth as well as plaque index (PlI) and periodontal screening index (PSI) values for the whole dentition.
Results: Two years after therapy, recorded CAL, PPD, BoP, GI, PlI and PSI scores revealed healthy periodontal conditions in 18 out of 20 treated teeth. Two teeth had suffered again from fragment fracture due to new traumata.
Conclusions: Adhesive fragment reattachment in periodontally healthy teeth affected by crown–root fractures had no detrimental impact on periodontal health over a time course of 2 years.

Key words: biological width; crown–root fracture; dental trauma; fragment reattachment; periodontal

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Traumatic tooth fractures are a common reason for seeking dental care. Among them, crown–root fractures pose a special challenge due to the involvement of the enamel, dentine and cementum in the fracture plane. Depending on a possible exposure of the pulp, uncomplicated crown–root fractures are distinguished from complicated crown–root fractures (Andreasen 1970).

The incidence of crown–root fractures has been reported to be 2% in the deciduous dentition and 5% in the permanent dentition (Andreasen 1970). Most frequent causes are injuries inflicted by falls and blows, as well as sports, bicycle and car accidents (Andreasen 1970, Forsberg & Tedestam 1993).

Typical clinical signs of the presence of a crown–root fracture are pain while chewing and a variably expressed mobility of the coronal tooth fragment. Radiographically, the oral extension of the fracture line is often difficult to assess due to its mostly perpendicular position to the central beam, the close proximity of the fragments and the overlap of fracture line with the alveolar bone.

The direction and extension of crown–root fractures are mostly determined by the direction of the traumatic force afflicting the tooth. In anterior teeth, typically the fracture line originates somewhat coronal to the gingival margin on the vestibular aspect of the crown and ends subgingivally close to the alveolar bone crest on the oral aspect of the tooth. Subgingival fracture lines in close proximity to the alveolar bone, however, imply considerable challenges for subsequent restorative interventions including the violation of the biological width. The concept of the biological width is mostly based on the data of Gargiulo et al.

Conflict of interest and source of funding statement
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(1961). In healthy uninflamed periodontia, they observed an average vertical dimension of the connective tissue attachment of 1.07 mm, followed by an epithelial attachment of 0.97 mm and an average sulcular depth of 0.69 mm. Similarly, Vacek et al. (1994) observed a vertical distance of approximately 2 mm between the alveolar bone crest and the bottom of the gingival sulcus. Several studies revealed that the placement of restoration margins closer than 2 mm towards the alveolar bone level results in gingival inflammation and subsequent loss of connective tissue as well as alveolar bone height, clinically visible as periodontal recessions or deepened periodontal pockets (Tal et al. 1989, Günay et al. 2000). As a consequence, Ingber et al. (1977) as well as Padbury et al. (2003) concluded that a minimum vertical distance of 3 mm should be provided between restoration margins and the alveolar bone crest. In order to maintain the biological width in teeth suffering from crown–root fractures, various therapeutic interventions have been described in the literature. In superficial fractures without pulp exposure, an adhesive reattachment of the coronal fragment after removal of the subgingival cervical fragment extensions is possible. The long-term prognosis of this therapeutic option, however, is unknown so far. Established standard therapy for crown–root fractures, however, has been crown lengthening by resective osseous surgery (McDonald et al. 1982). Further therapy options comprise orthodontic/surgical extrusion of the root fragment, as well as extraction of the afflicted tooth and replacement by a fixed bridgework or a dental implant (Ingber 1976, Kahnberg 1988, Leroy et al. 2000, Meiers & Freilich 2001, Villat et al. 2004). With the exception of the fragment reattachment in superficial fractures, all other therapy options incur costly and time-consuming restorative therapy.

Because of the development of reliable resin composites and bonding systems, tooth fractures limited to enamel and dentine are nowadays routinely restored by adhesive reattachment of the coronal fragment mostly without the necessity of additional restorative interventions. Various case reports confirmed that despite various technical problems, adhesive fragment reattachment is also possible in teeth affected by crown–root fractures (Koparal & Ilgenli 1999, Nogueira Filho Gda et al. 2002).

The purpose of this case report study was to evaluate the impact of adhesive fragment reattachment in periodontally healthy teeth suffering from crown–root fractures on various parameters of periodontal health over a time course of 2 years.

Material and Methods

Study subjects

A total of 20 initially periodontally healthy teeth (PSI score $\leqslant 2$) with crown–root fractures in 18 patients (10 males, eight females), which were treated by adhesive fragment reattachment, have been evaluated. All patients were seeking emergency dental care at the dental school of the University of Wuerzburg in the years 2003–2006. Patient age varied from 11 to 78 years (median: 26.28 years). Four of the fractured teeth were molars, seven were premolars, two were canines and seven were incisors. In all cases, the fracture line was oblique and <1 mm away from the alveolar bone level. In five teeth, the broadly exposed pulp chamber required endodontic therapy subsequently. Another three teeth had already been treated endodontically before the fracture trauma.

Therapy scheme

Initial measures

Nineteen out of 20 fractures were treated within 5 days after trauma. In one case the fragment was reattached 2 months after trauma. Before the definitive reattachment, fragments remained either in situ and were splinted with a provisional ligature splint and an interfacing layer of calcium hydroxide between the fragment and the root stub. If provisional splinting of the fragment was not feasible, the surface of the root stub was sealed with a calcium hydroxide cementum and subsequently covered with a temporary resin (Systemp Onlay®, Ivoclar Vivadent, Schaan, Liechtenstein). Coronal fragments, that could not be kept in situ were stored in phosphate-buffered saline (PBS) until definitive fragment reattachment.

Fragment reattachment

All fracture sites were exposed under local anaesthesia by the preparation of a surgical flap (Fig. 1). If the crown fragment could be easily reattached to the root stub without bleeding or mechanical obstacles, no ostectomy was performed. In six teeth, a maximum of 0.5 mm of vertical bone height was removed using a rose burr and sterile PBS as a coolant. Haemostasis was secured by sterile cotton pellets impregnated with adrenaline (American Dental Systems GmbH, Vaterstetten, Germany).

Fig. 1. Tooth 11: Preparation of a mucoperiostal access flap.

Fig. 2. Tooth 11: Situation after adhesive reattachment of the crown fragment.

After carefully cleaning the fracture sites on the root stub and the crown fragment, enamel surfaces adjacent to the fracture line were etched for 30 s using a 35% phosphoric acid gel (Ultra-Etch®, Ultradent, South Jordan, UT, USA). Subsequently, the crown fragment was adhesively reattached to the root stub using Optibond FL® (KerrHawe, Biggio, Tessin, Switzerland) and Tetric flow® (IvoclarVivadent) (Fig. 2). Curing was performed by a LED curing light (Elipar™ FreeLight 2, 3M ESPE, Germany) held at the fracture line at different angles for 30 s each. After diligently removing any excess resin using a scalpel blade and oscillating files (Proxoshape®, Kavo, Biberach, Germany), the flap was repositioned using 5.0 non-resorbable sutures. Subsequently, occlusion was checked using an occlusion foil (Hanel foil, Coltene Whaledent, Altsatten Switzerland) and eventual occlusal interferences were removed by a fine diamond burr. Finally, patients were instructed to refrain from toothbrushing at the operation site for 10 days and were instructed to use a 0.2% chlorhexidine mouth rinse twice daily as a substitute. After 10 days post surgery, the sutures were removed and patients resumed normal oral hygiene efforts (Fig. 3).

Fig. 3. Tooth 11: Clinical situation 2.5 years after adhesive reattachment.

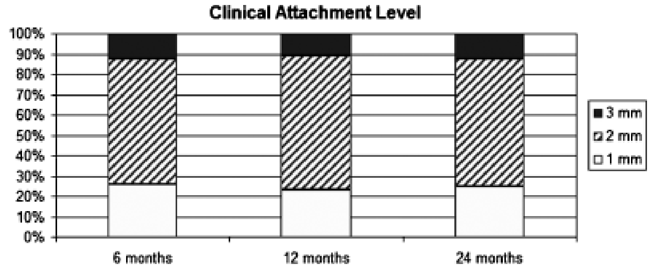

Fig. 4. Frequency distribution of the maximum clinical attachment level score observed at the fracture sites.

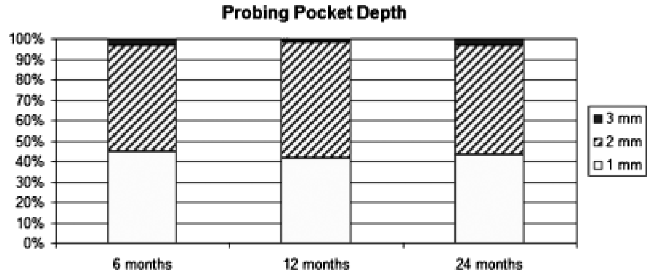

Fig. 5. Frequency distribution of the maximum probing pocket depth score observed at the fracture sites.

Monitoring

At 6, 12 and 24 months post surgery, patients were recalled and the following parameters of periodontal and gingival health were recorded:

1. Clinical attachment level (CAL);
2. probing pocket depth (PPD);
3. bleeding on probing (BoP);
4. plaque index [PlI; (Silness & Löe 1964)];
5. gingival index [GI; (Löe & Silness 1963)];
6. periodontal screening index (PSI);
7. radiographical findings.

1/2. *CAL* and *PPD*: CAL and PPD were recorded for each treated tooth at six sites in single-root teeth and at eight and 10 sites in maxillary molars and mandibular molars, respectively. All measurements were performed by one examiner using a manual periodontal probe (UNC 12 probe, Hu-Friedy, Chicago, IL, USA). Measurements were made to the nearest mm. For data analysis, only probing sites adjacent to subgingival parts of the fracture line were included.

3. *BoP*: The presence of BoP was recorded immediately after the measurements of CAL and PPD.

4. *PlI*: Plaque accumulation was quantified on all teeth using the PlI (Silness & Löe 1964). Subsequently, plaque-covered tooth surfaces were demonstrated to the patient and if necessary effective plaque control measures were practically instructed.

5. *GI*: Gingival inflammation on the test teeth (TT) was quantified using the GI (Löe & Silness 1963).

6. *PSI*: To verify the overall periodontal health of the treated patients, the PSI was recorded. At baseline, a PSI score for all teeth, with the exception of the fractured teeth, was recorded. At the reevaluation appointments, a PSI score for all teeth was recorded.

7. *Radiographical Findings*: To verify possible hidden fractures or pathological changes in the alveolar bone in proximity to the fracture sites or periapical lesions, dental X-rays were taken immediately after trauma and 2 years after adhesive fragment reattachment using Rinn film holders. Quantification of alveolar bone height levels was not performed.

Statistical analysis

As a lack of test power induced by the small sample size and the number of evaluated parameters did not allow a meaningful inferential statistical analysis, a purely descriptive presentation of the data was chosen.

Results

Twenty-four months post surgery, 18 out of 20 reattached crown–root fragments were still in situ. Two fragments were lost due to a sports accident and a blow with a glass bottle, respectively. The affected teeth were both front teeth (31, 13), one (13) displaying a root canal filling. The retention time in both failure cases was >1 year. There were no signs of a technical failure of the adhesive bond.

CAL

The frequency distributions of the observed CALs 6, 12 and 24 months after adhesive fragment reattachment are depicted in Fig. 4. Data analysis revealed that the vast majority (88%) of recorded CALs did not exceed 2 mm. None of the evaluated sites displayed CAL $>$ 3 mm.

PPD

The frequency distributions of the recorded PPDs 6, 12 and 24 months after adhesive fragment reattachment are depicted in Fig. 5. The analysis of the data revealed that in none of the probed sites did the PPDs exceed 3 mm. The vast majority (97%) of sites displayed PPD in the range of 1–2 mm.

BoP

Figure 6 displays the frequency distributions of probing sites with positive or negative bleeding on the probing score at 6, 12 and 24 months post fragment reattachment. Data analysis exhibited a low (13%) frequency of sites positive for bleeding on probing throughout the observation period. Positive bleeding scores were associated with high-PlI scores.

PlI

Figure 7 displays the frequency distribution of the PlI scores recorded for all teeth [control teeth (CT)] and the fractured teeth TT. PlI scores were determined for the CT group on the day of operative fragment reattachment (OP), as well as 6, 12 and 24 months afterwards, while for the TT group, at the day of operative fragment reattachment, no useable data could be obtained. PlI scores were already low at baseline and improved further by oral hygiene instructions given during the observation period. Data analysis shows a predominance of low PlI scores for all evaluated teeth throughout the observation period and no significant differences between the TT and the CT.

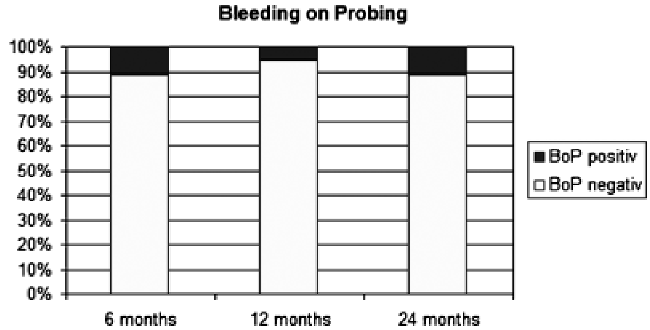

Fig. 6. Frequency distribution of bleeding on probing (BoP) observed at the fracture sites.

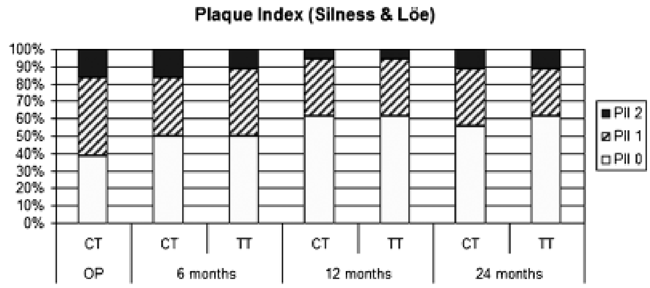

Fig. 7. Frequency distribution of the plaque index (PlI) scores on tooth surfaces adjacent to the fracture sites test teeth (TT) and on all other teeth control teeth (CT).

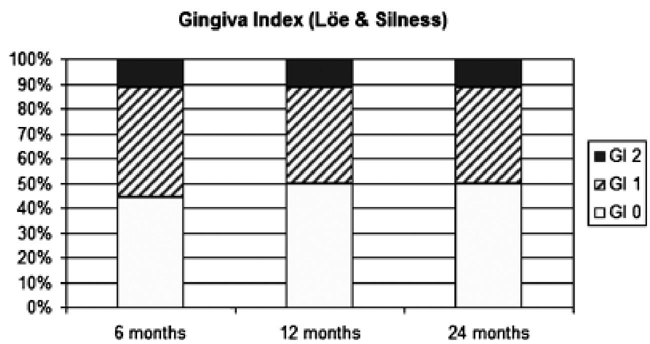

Fig. 8. Frequency distribution of the Gingiva Index (GI) scores observed adjacent to the fracture sites.

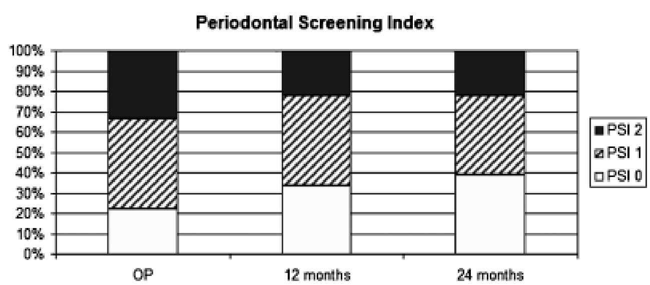

Fig. 9. Frequency distribution of periodontal screening index (PSI) scores recorded.

GI

The distribution of GI scores recorded at the fractured teeth 6, 12 and 24 months after fragment reattachment is depicted in Fig. 8. Data analysis revealed a predominance of low GI scores. Only two out of 18 teeth had a GI score of 2, indicating established gingivitis. High GI scores were always associated with high PlI scores.

PSI

The distribution of recorded PSI scores at baseline, 12 and 24 months is shown in Fig. 9. The absence of PSI scores $\geqslant 3$ indicates that the patients evaluated did not have periodontal disease in any tooth throughout the observation period.

Radiographical findings

The radiographical evaluation of the restored teeth could not detect the development of periapical lesions, evident interproximal bone loss or any other related pathological changes between baseline and 24 months.

Discussion

The present case report series demonstrate the successful therapy of crown–root fractures in periodontally healthy teeth by adhesive fragment reattachment without a subsequent negative impact on established parameters of periodontal health. This is in contrast to still commonly accepted clinical guidelines for the placement of restoration margins. In all treated cases, the distance between the fracture line and the alveolar bone level was 1 mm and therefore infringing the biological width postulated by Gargiulo et al. (1961). Although widely accepted, there is little scientific evidence for the concept of biological width. Ramfjord (1988) questioned the justification of osseous resections solely for the purpose of re-establishing the biological width, and placed emphasis instead on an optimal access for the preparation of a proper marginal fit for the restoration margins.

Non-adhesively cemented restorations inevitably display a margin gap, which is readily colonized by oral microorganisms, inducing an inflammatory response in the adjacent tissues. Because of the adhesive fragment reattachment, the teeth evaluated in this study lack a distinguishable margin gap and were free of any excessive restorative material, which otherwise might have allowed the accumulation of bacterial plaque within the gingival sulcus. Clinically, most of the adhesively restored teeth showed no or only mild symptoms of gingival inflammation, and the formation of periodontal pockets or periodontal recessions was not observed. Concomitantly, visible plaque formation on the supragingival tooth surfaces adjacent to the fracture sites was low. Established gingivitis, defined by a GI score of 2, was rare and always associated with visible plaque accumulations. This supports the conclusions that bacterial plaque formation and not a lack of biocompatibility of the restorative material itself is the aetiologic factor behind gingival inflammation observed in the vicinity of subgingival restoration margins infringing the biological width. In the present study, established gingivitis defined by a GI score of two was rare and always associated with visible plaque accumulations, due to localized oral hygiene deficits, as no histological samples could be obtained from the patients, the real extent of a possible inflammatory reaction towards the composite resin within the restored fracture line remains speculative. According to the findings of van van Dijken et al. (1987a, b), however, the subgingival margins of properly placed composite resin fillings are in general well tolerated by the adjacent tissues. This is in good agreement with histological data published by Dragoo (1997), who reported the formation of epithelial and connective tissue attachments on subgingivally placed glass-ionomer restorations.

For the treatment of supragingivally positioned isolated-crown–fractures, the adhesive fragment reattachment has become an established standard procedure due to its minimally invasive nature, mechanical durability, restoration of function, excellent aesthetics and a very favourable cost–benefit ratio (Andreasen et al. 1995, Murchison et al. 1999, Andreasen 2001, Olsburgh et al. 2002, Rappelli et al. 2002).

In crown–root fractures, however, to the best of our knowledge, adhesive fragment reattachment has not been systematically reviewed so far.

Particular challenges for the adhesive fragment reattachment in teeth suffering from crown–root fractures are the proper exposure of the fracture surfaces, efficient haemostasis and a firm bonding process between the root stub and the crown fragment not impaired by moisture or bleeding. To ensure maximum bonding strength in all presented cases, a multi-bottle bonding system was applied, which proved to result in higher bonding strength values than single bottle systems (Pagliarini et al. 2000, Farik et al. 2002, Goracci et al. 2004). Another important parameter seems to be the storage environment of the fragment. Farik et al. (1999) demonstrated that a fragment drying for more than 1 h prior to before bonding of the fragment showed a decline in fracture strength caused by collapsed collagen fibres. Therefore, fragments that did not remain in situ until the definitive fragment reattachment were stored in PBS.

The loss of two fragments during the observation period was not due to a mechanical failure based on poor bonding but originated from the induction of new mechanical traumata, which presumably would have also resulted in the fracture of naturally sound teeth. This observation is also in good agreement with observations made by Andreasen et al. (1995) on the main reasons for the loss of adhesively attached crown fragments.

From a toxicological point of view, the subgingival use of adhesives and composite resins must be critically discussed. Ingredients like monomers, co-monomers and additives may be released in elevated concentrations after incomplete light curing (Geurtsen 1998, Emami & Soderholm 2003, Sigusch et al. 2007). Recent evidence stresses, furthermore, the potential genotoxic properties of these compounds and their detrimental influence on cellular homeostasis, dentinogenesis or tissue repair (Schweikl et al. 2006). The clinical relevance of these data, however, still needs to be established.

Clinical evidence so far suggests that properly cured and finished composite resins may also be used in subgingival locations, as available clinical studies (Dragoo 1997, van Dijken et al. 1987a, b) reported uneventful and favourable reactions of gingival soft tissues towards composite and glass-ionomer filling materials. A recent investigation by Konradsson & van Dijken (2005) showed that subgingivally placed margins of composite resin restorations did not affect the concentrations of IL-1α, IL-1β and IL-1ra in the gingival crevicular fluid of gingivally healthy sites, nor of sites with initiated plaque-induced gingival inflammation.

Clinically, none of the patients evaluated in this case report series suffered from periodontal disease indicated by the lack of PSI scores >2 at baseline. Adhesive fragment reattachment was not associated with PSI scores >2 in any of the patients at the end of the 2-year observation period, suggesting the absence of progressive periodontal disease. Also, the evaluation of PPD, CAL, BoP and GI scores on the fractured teeth failed to suggest a detrimental effect of adhesive fragment reattachment in crown–root fractures on periodontal health in previously periodontally healthy subjects. The majority of tooth surfaces were plaque-free and none of the patients displayed PlI scores >2 on any tooth surface indicative of effective oral home care.

The authors are aware of the limitations of this investigation in that it is basically a series of case reports treated by a standardized treatment scheme and particularly lacking the inclusion of the analysis of contralateral CT as well as a quantitative radiographical analysis of eventual alveolar bone height changes. Ideally, a randomized prospective study should evaluate the adhesive restoration of similar defects in identical tooth groups in comparison with established standard procedures. In the present case series, the universal validity of the data is limited by the fact that crown–root fractures in a variety of tooth morphotypes (molars, premolars, canines and incisors) were evaluated and the location of the fracture site itself (buccally/orally/interproximally) was not consistent but comprised various locations, which only shared a fracture line in close proximity to the aveolar bone crest. In some of the cases, minor ostectomy was performed while in others alveolar bone architecture remained completely untouched, introducing further variations into the data obtained from a relatively small number of cases. There are well-established conventional radiographical methods to monitor alveolar bone-level changes but in this patient sample the vast majority of fracture sites were located buccally or orally and were therefore not amenable to two-dimensional radiographical analyses. The evaluated number of interproximal sites alone was too small for a meaningful statistical evaluation of the data. Only the use of current dental cone beam CTs might have allowed a comprehensive quantification of alveolar bone levels in all of the sites.

Nevertheless, due to a complete lack of sound evidence derived from such controlled-clinical trials, the findings of this comparatively large case report series may provide some useful information for the clinical management of crown–root fractures in periodontally healthy teeth. The high rate of clinical success 2 years after therapy observed in the present cohort of patients suggests that adhesive fragment reattachment may be a clinically feasible and minimal invasive therapy option also in crown–root fractures, which particularly does not foreclose the subsequent application of more invasive traditional therapeutic schemes in case of a primary therapy failure.

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(Correction added on 25 August 2009, after first online publication: The corresponding author's email address was corrected.)

Clinical Relevance

Scientific rationale for the study: The purpose of this study was to evaluate the impact of adhesive fragment reattachment in crown–root-fractured teeth without preceding surgical adjustment of the distance between the alveolar bone and the fracture line on established parameters of the periodontal health.

Principal findings: Two years after adhesive fragment reattachment, the periodontal conditions of treated teeth were healthy, with neither clinically visible signs of inflammation nor the formation of periodontal pockets or recessions.

Practical implications: This case series suggests that adhesive fragment reattachment is a clinically feasible and minimally invasive alternative treatment option for restoring crown–root fractured teeth.