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Review

Periodontal Perspectives in the Treatment of Tooth Fractures in Permanent Dentition: A Decision-Making Process

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Abstract: Tooth fractures represent a very common scenario, mainly among children and young adults, thus affecting permanent dentition most of the time. These fractures may involve either the tooth crown or the root or both, including the dental tissues as well. Their treatment can be very demanding for the majority of dentists, including Restorative Dentistry specialists, as reported by the literature. Therefore, the aim of this review article is to provide a decision-making procedure regarding the periodontal-restorative approaches of dental fractures in permanent dentition, based on the revision of the existing scientific evidence.

Keywords: tooth fractures; periodontium; guideline; root canal therapy; traumatology

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1. Introduction

Dental fractures are a disruption of the natural tooth architecture that can involve different portions of the dental structure (crown, root or both) and tissues (enamel, cementum, dentin and pulp). The management of fractures of permanent teeth represents a challenging clinical scenario often requiring an interdisciplinary approach [1]. Unlike injuries located in other parts of the body, the hard dental tissues do not undergo a consequent healing process. Data from a study based on the 1988–1991 National Health and Nutrition Examination Survey (NHANES III) on 7.707 participants aged 6 to 50 years reported a prevalence of 25% of incisors trauma with a mean number of 2 involved teeth and maxillary central incisors as the most frequent site [2]. Enamel fracture was the most prevalent traumatic condition, and a higher occurrence was associated with the male gender and the older age, irrespective of their ethnicity. More recently, the International Association of Dental Traumatology published the guidelines for the management of traumatic dental injuries, reporting that 25% of all school children experience dental trauma and 33% of adults have experienced trauma to the permanent dentition, with the majority of the injuries occurring before age 19 [3,4]. Luxation injuries are the most common traumatic dental injuries in primary dentition, whereas crown fractures are more commonly reported for permanent teeth [3]. As a consequence, proper diagnosis, treatment planning and follow-ups are important factors in order to achieve successful outcomes.

Restorative procedures are mostly required to manage such dental defects, and the appropriate placement of restoration margins with respect to periodontal tissues represents one of the most critical aspects of the treatment [5,6]. Kosyfaki et al. focused their systematic review on the interactions between prosthetic dental crowns and periodontal tissues [7]. Their results indicated that a prosthetic crown margin with a supragingival location was the

most beneficial type of restoration in terms of periodontal health. In contrast, restorations with juxta-gingival or subgingival margins resulted in increased plaque accumulation, leading to more severe gingival inflammation, with additional increased pocket depths, loss of attachment and gingival recessions [8,9]. In this perspective, knowledge of the dimensions of the junctional epithelium and the connective tissue attachment, namely Supracrestal Tissue Attachment (STA), is of paramount relevance [10]. Schmidt et al. reported that no universal dimension of STA seems to exist [11]. Mean values of STA width were obtained from two meta-analyses and ranged from 2.15 to 2.30 mm, even though large intra- and inter-individual variances were observed. The tooth type and tooth site, the presence of a restoration and periodontal diseases/surgery affected the dimensions of the STA width. Therefore, in the case of combined surgical-restorative approaches to treating fractured teeth, the establishment of a proper STA should be assessed prior to the commencement of the procedure itself. In addition, aesthetic, psychological and functional implications must be also considered [12].

Even though a wide discussion with useful suggestions has been reported in the recent guidelines for the management of traumatic dental injuries published by the International Association of Dental Traumatology [4], no information was given about the re-establishment of the STA during the different treatment approaches.

Therefore, the aim of this study is to provide a decisional tree for the treatment of dental fractures in permanent dentition focusing on the periodontal attachment area in order to provide a clinical guide for dental restoration.

2. Materials and Methods

In the proposed clinical guide, according to a previous classification of traumatic dental injuries [4], the following different fracture morphologies have been used:

Fracture Morphology (Figure 1)

Horizontal: the fracture line is perpendicular to the tooth's long axis.

Oblique: the fracture line has mainly an oblique direction.

Vertical: the fracture line is parallel to the tooth's long axis.

These morphotypes can involve the crown and/or the root surface.

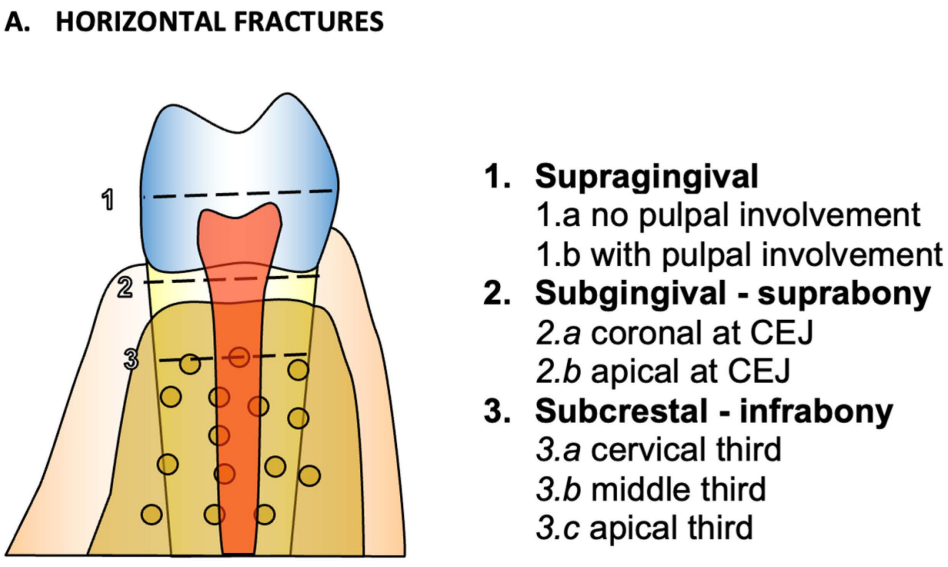


Figure 1. *Cont.*

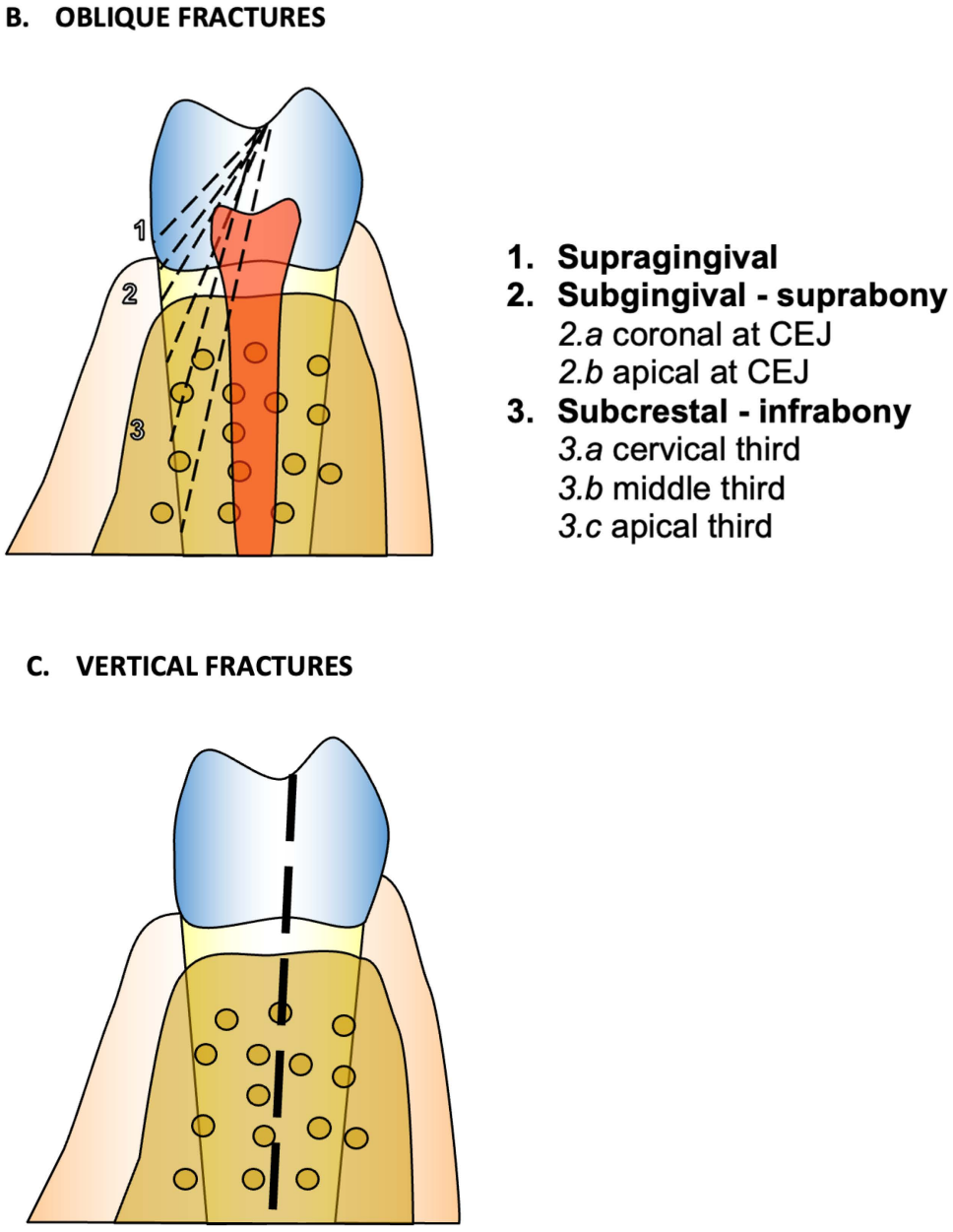


Figure 1. Dental fracture classifications based on periodontal impact: (**A**) horizontal; (**B**) oblique; (**C**) vertical.

Relationship with the Periodontium

1. Supragingival: Fracture line coronal to the gingival margin with (A) or without (B) involvement of the pulp.

2. Subgingival: Fracture line apical to the gingival margin with or without involvement of the pulp.

Two sub-categories can be identified:

A. Intrasulcular Supra-Attachment Level fracture (ISAL): fracture line within the gingival sulcus.
B. Supracrestal Infra-Attachment Level fracture (SIAL): fracture line within the STA.

1. Subcrestal: fracture line extending beyond the bone crest.

Three sub-categories can be identified:

A. Subcrestal fracture line at the *cervical third* (Figure 2).
B. Subcrestal fracture line at *middle third* (Figure 3).

C. Subcrestal fracture line at the *apical third* (Figure 4).

Figure 2. Horizontal subcrestal attachment level fracture (SAL). Coronal third.

Figure 3. Horizontal subcrestal attachment level fracture (SAL). Middle third.

Figure 4. Horizontal subcrestal attachment level fracture (SAL). Apical third.

3. Decision-Making Process for Tooth Fractures

According to the abovementioned crown–root fracture classification, the following clinical guidelines are suggested.

3.1. Horizontal Fractures

1. Supragingival fractures

These fractures affect the crown and are classified according to the presence of the pulp involvement:

1. A. No pulp involvement (Figure 5)

These fractures can involve enamel alone or may extend to the dentin. The tooth vitality is preserved in most of the enamel fractures. In the case of the involvement of the dentin, the pulp vitality depends on the extension of the fracture and the timing of the exposure to the oral cavity. Bacteria and their by-products can enter the dentin tubules and reach the pulp, triggering an inflammatory response [13]. A positive response to

pulp testing in this scenario varies from 75% to 98%. Furthermore, these tests need to be repeated regularly to exclude delayed necrosis and the need for a root canal treatment (RCT). However, pulp testing should be planned a few weeks after the trauma in order to exclude an initial negative response following the trauma [3,13].

Figure 5. Oblique supragingival fractures without pulp involvement.

3.2. Treatment

Restoration with Adhesive Technique

This can be obtained either by repositioning and bonding the fractured fragment or via a composite restoration [13,14].

Browning et al. reported a mean duration of 5 years in the case of Class IV restorations. In 36%, the cause of class IV replacement was due to decay recurrence, marginal failure and discolouration, while in 47%, the cause was due to a composite fracture. Ceramic crowns or veneers might be required in the case of repeated failure of the composite build-up technique [15].

3.3. Follow-Up

In the case of vital pulp, it was recommended to perform follow-up visits at 6–8 weeks and 3, 6 and 12 months, inclusive of pulp testing and radiographic assessment [3,16].

1. B. Pulpal Involvement

The diagnosis of pulpal involvement is obtained via clinical examination of the fractured area and the detection of the exposed pulp. Thermal and mechanical sensitivity and dehydration are due to the dentin tubules opening. Usually, pulp testing elicits a positive response (Figure 6). In addition, tooth mobility and maturation of the root apex should be assessed according to previous indications [4].

Figure 6. Oblique supragingival fractures with pulp involvement.

3.3.1. Treatment

Pulp Management and Adhesive Technique Restoration

With regards to the management of pulp exposure, there are conservative options such as pulp capping and partial pulpotomy or a more definitive treatment such as pulpectomy [17,18].

Conservative procedures are ideal in the absence of complete apex maturation, recent pulp exposure and the absence of inflammation [19]. The restorative options are similar to the 1A scenario.

Follow-Up

As per fractures with no pulp exposure, follow-up visits are recommended at 6–8 weeks and 3, 6 and 12 months, inclusive of pulp testing and radiographic assessment [3,16].

4. Subgingival Fractures

2. A. Intrasulcular Supra-Attachment Level fracture (ISAL)

With regard to the periodontal tissues, the fracture line is within the gingival sulcus, coronal to the junctional epithelium. The tissues involved are enamel or root cementum, dentin and the pulp.

4.1. Treatment

Endodontic treatment (in the case of pulp involvement) and adhesive restoration are indicated. If the fractured fragment is not available, direct or indirect adhesive restorations are indicated (with or without cervical margin relocation). As an alternative, forced tooth extrusion may also be considered before restoration. Tooth mobility and maturation of the root apex should also be assessed [4,20].

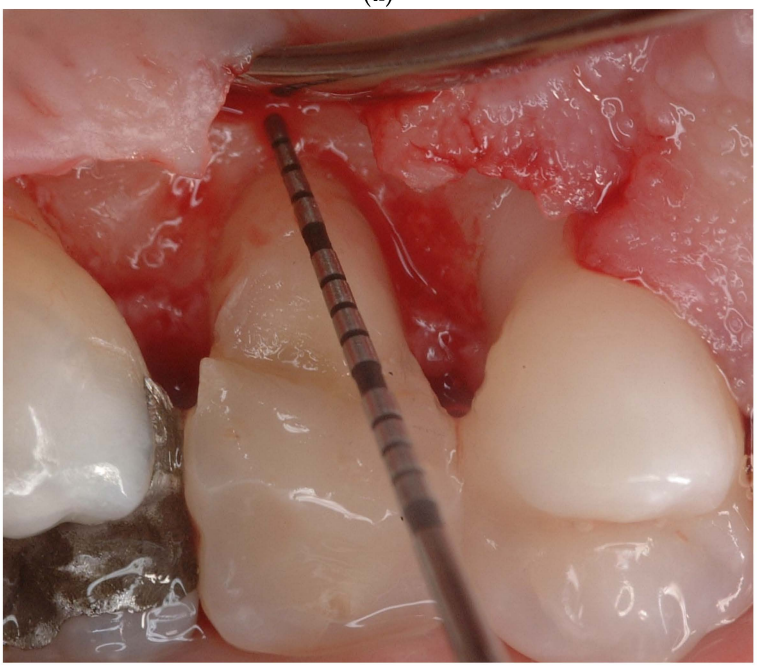
4.2. Follow-Up

As per supragingival fractures with no pulp exposure, follow-up visits are recommended at 6–8 weeks and 3, 6 and 12 months, inclusive of pulp testing and radiographic assessment [3,16]. In the case of endodontic treatment, follow-up visits at 12 months are recommended.

2. B. Supracrestal Infra-attachment level fracture (SIAL)

Fractures of the cervical third of the root. The fractured fragment has clear mobility but is held by the periodontal fibres. The fracture line can be located within the STA (Figure 7).

(**a**)



(**b**)

Figure 7. (**a**) Oblique subgingival fractures (2A)—Supracrestal Infra-attachment level fracture (SIAL) fracture. (**b**) Location of the fracture line coronal to the bone crest.

4.3. Treatment

In the presence of the fractured fragment, as suggested by previous case reports [18–20], the treatment consists of endodontic treatment, exposure of the fracture line via periodontal access flap and adhesive reattachment of the fragment [21].

In the absence of the coronal fragment or a lack of ideal adaptation of the fracture margins, a crown-lengthening procedure is advised either via surgical or orthodontic procedures. However, to maintain the evenness of the gingival margin, osteotomy is also advised for the adjacent teeth. As a consequence, in the anterior dentition, the surgical option should be considered only in the case of multiple teeth fractures or if involving a single tooth when only palatal or minimal osteotomy is required. In contrast, orthodontic

extrusion should be considered in cases of single teeth in an aesthetic area requiring significant ostectomy to expose the fracture margin, although a smaller root diameter resulting from tooth extrusion may provide improper aesthetics at the cervical site [20].

It is always recommended to check the tooth mobility and the root apex maturation in order to provide proper treatment [4].

4.4. Follow-Up

A 3-month follow-up is recommended for the first year [3,21].

3. Subcrestal Attachment Level fracture (SAL)

In the case of a subcrestal attachment-level fracture, both the pulp and the periodontium are involved. According to the area involved, they can be on the apical (a) (Figure 6), middle (b) (Figure 7), or coronal (c) (Figure 8) third of the root. It is more common to observe a mid-third fracture, followed by apical and coronal ones [22].

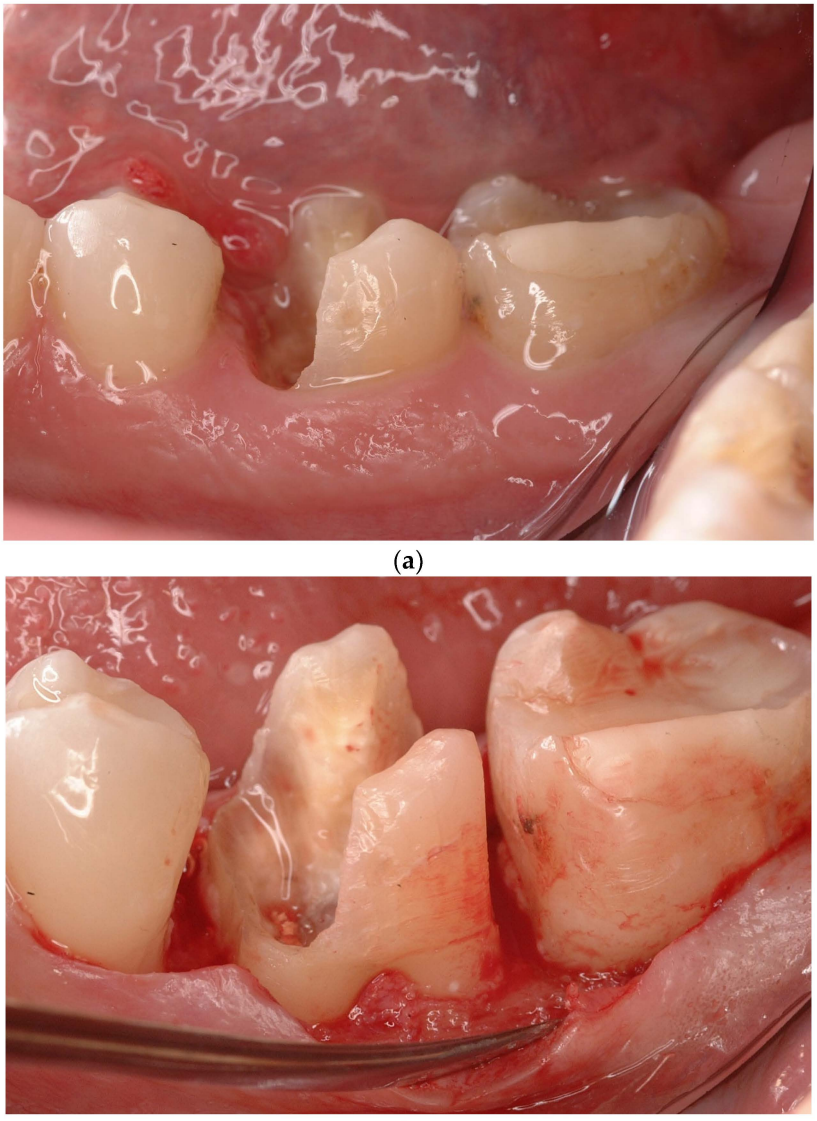


Figure 8. (**a**) Oblique supracrestal fractures—Subcrestal Attachment Level fracture (SAL) fracture. (**b**) location of the fracture line near the bone crest.

4.5. Treatment

Tooth loss is not necessarily the outcome of this type of fracture. Healing and the absence of symptoms together with a positive response to pulp testing have been reported [23,24]. Three types of healing have been described:

1. Calcified tissue formation: This is normally observed in the case of minimal displacement of the fragment. The pulp remains responsive to thermal stimuli. Cement, dentin and bone tissue contribute to the stabilization of the fracture. Tertiary dentin forms in the canal.

2. Connective tissue formation: Periodontal ligament fibres surround the two fragments with the formation of a new apex at the coronal fragment.

3. Bone and connective tissue formation: This type of healing is normally observed when there is more distance between the two fragments.

3. A. Subcrestal Attachment Level fracture (SAL)—cervical third.

Treatment options #1: Root Canal Treatment, Crown lengthening, Restoration.

The treatment is similar to that of subgingival horizontal supracrestal fractures and involves endodontic treatment, crown lengthening and tooth restoration [21,25,26]. However, a proper radiographic assessment should guide the treatment since an unfavourable crown/root ratio (more than 1:1) or an aesthetic impairment represents possible limitations to a crown-lengthening procedure.

Treatment options #2: Extraction and replacement with implant therapy or adhesive restoration

In the case of a complication or a lack of other therapeutic options, implant therapy represents a reliable option. Anderson et al. replaced single edentulism due to dental trauma, reporting 97.5% success at a 5-year follow-up [27]. However, in the case of young subjects, rehabilitation might need to be postponed to allow completion of the bone growth in order to avoid implant infra-position due to further growth of the alveolar process and the consequent permanence of the implant in a more apical position with evident aesthetic and functional repercussions. In this case, or in the case of a reduced amount of bone thickness, an adhesive restoration (Maryland Bridge) represents a possible definitive alternative for the resolution of a single edentulism in an aesthetic area.

Ridge augmentation and/or orthodontic treatment (*implant site development technique*) might be required to increase and recreate an adequate space/volume for implant placement [28]. Root retention can be also an option to maintain the ridge volume in cases where the presence of infection can be excluded [27].

3. B. Subcrestal Attachment Level fracture (SAL)—middle third

This is the most frequent type of root fracture [22].

Treatment option #1: Monitoring

Considering the high healing potential (80%) and 86% long-term survival, a conservative approach is preferable [29,30].

In the absence of mobility, no further action should be taken. Alternatively, a repositioning of the fragment and its splinting is required for an average time of 3–4 weeks [31]. In cases of an open apex, splinting is not suggested as, in this instance, hard tissues will drive the healing. Regular pulp tests and radiographic assessment will be needed to exclude necrosis [3,32–34].

Treatment option #2: Endodontic treatment of the coronal fragment

The pulp of the apical fragment normally remains vital, while the cervical part could easily necrotize [35]. In this instance, RCT of the coronal fragment is indicated. Executing am RCT also in the apical portion of the tooth is not likely to succeed due to debris accumulation in the fracture rim [33,36,37]. However, the large diameter of the canal at the fracture point and the presence of diastasis might not allow good disinfection and adequate root filling. Additionally, the contaminated tissue might not be completely removed, causing inflammation of the surrounding area. The use of calcium hydroxide or MTA has been suggested to stimulate hard tissue healing [34,36,38,39].

Treatment option #3: Extraction of the apex and splint of the coronal fragment

In the event of necrosis of the whole pulp or failure of RCT, extraction of the apical fragment and a coronal RCT can be planned [36]. The increased mobility of the coronal fragment can be controlled with a splint that can be kept until full stabilization is achieved [33].

4.6. Follow-Up

Examination, pulp testing and radiographic assessment should be carried out after 4 and 8 weeks. At this stage, it should be possible to remove the splint. Afterwards, 4-, 6- and 12-month and subsequent annual follow-ups should be carried out [16].

3. C. Subcrestal Attachment Level fracture (SAL)—apical third

The treatment options concerning this type of fracture resemble the ones available for the horizontal fractures of the mid-third.

In all three different conditions, tooth mobility and maturation of the root apex should be assessed for eventual proper treatment [4].

5. Oblique Fractures

Oblique fractures can involve the crown and/or the root portion of the tooth.

1. Supragingival

These crown fractures can be classified according to the pulpal involvement.

5.1. No Pulp Involvement

Treatment option: Adhesive dentistry.

The technique resembles that used for horizontal fractures.

5.2. With Pulpal Involvement

Treatment options: Endodontic Treatment and Adhesive dentistry.

The same procedure is used for horizontal fractures with pulp involvement.

2. Subgingival

Suprabony

The fracture line is subgingival but does not extend below the bone crest. The periodontal tissues contribute to the stability of the fragment. In terms of the relationship with the periodontium, the apical portion of the fragment can be located in the sulcus or within the junctional epithelium/connective fibres.

2. A. Suprabony—Coronal to CEJ

This involves enamel and dentin, but the pulp might not be necessarily affected [40]. Andreasen et al. suggest that in young subjects, the pulp is less likely exposed due to a non-complete eruption [23]. The fracture line can be present within the sulcus or the junctional epithelium coronal to the CEJ.

Treatment option: Adhesive dentistry with or without endodontic therapy.

Eichelsbacher et al. reported a case series of 20 subgingival oblique fractures treated with adhesive dentistry only [40]. Koparal et al., in a case report, documented access flap, RCT and adhesive dentistry due to pulp exposure [41].

2. B. Suprabony—Apical to CEJ

The fracture reaches the cervical third of the root and, therefore, enamel, dentin and cementum are involved. It invades the connective attachment and STA. The pulp may not be necessarily affected.

Treatment options: Crown lengthening (with or without orthodontic extrusion), adhesive dentistry and, if needed, endodontic therapy are required.

The procedure is similar to the one suggested for horizontal fractures [40,42].

Infrabony

All the tooth tissues are involved.

3. A. Cervical third

Treatment option #1: Endodontic therapy, Crown lengthening (with or without orthodontic extrusion) and Restoration.

The treatment is similar to that adopted for the suprabony apical to the CEJ.

Treatment option #2: Extraction and implant placement.

3. B. Middle and 3. C. Apical Third

The morphology of the fracture leans toward the vertical type. Overall, in such cases, a restorative approach is really challenging. Furthermore, bacteria and irritants coming from the gingival sulcus promote periodontal breakdown until the apical extension of the fracture [43]. The residual length of the root does not allow one to perform a crown lengthening.

Treatment options: Extraction and implant placement.

6. Vertical Fractures

They can involve only the root (either the full length or part of it) or also the crown. Normally, the fracture extends from the pulp canal to the periodontium and is more common in teeth that underwent endodontic treatment (Figure 9a,b).

(**a**) (**b**)

Figure 9. Vertical fracture. Clinical (**a**) and radiographic (**b**) view.

A vertical fracture presents a difficult diagnosis since, very often, there is a lack of clear signs/symptoms. Furthermore, the clinical features depend on the tooth, the position of the fracture and the periodontal status.

Clinical elements that may raise suspicion of a vertical fracture:

1. A long history of discomfort related to chronic infection with mild- to moderate-intensity pain, sometimes present during chewing.
2. Symptoms persist even following a correctly performed RCT.
3. Presence of swelling.
4. Sinus tract probing: isolated, narrow and deep periodontal pockets, usually adjacent to the fracture line. Bilateral if the fracture extends on both sides of the root.
5. Frequent dislodgment of pins/posts and crowns.
6. Separation between the two fragments, with a fracture line along the root.
7. Radiographic signs of fragment displacement or longitudinal radiolucencies.

6.1. Treatment Option: Extraction and Implant Placement

Extraction is the main treatment option in single-rooted teeth, and it should be planned in a timely manner to avoid further periodontal damage. Root amputation is an option in multi-rooted teeth [43].

6.2. Subgingival Margin Positioning and Violation of the STA

Apart from the literature on subgingival positioning of crown margins and the associated inflammatory reaction of the periodontium, there is a bulk of evidence related to the adhesive technique for temporary or permanent subgingival restorations associated with an invasion of the STA [21,25,44,45].

Dragoo et al. published a case series on subgingival restorations with a follow-up period of up to 3 years [44]. The authors reported no gingival inflammation, an increase in probing pocket depth and an increase in clinical attachment. Histologic examination indicated the presence of connective fibres and junctional epithelium at the restoration margins. The accuracy in the adaptation of the restoration margins is of paramount importance in reducing plaque retention.

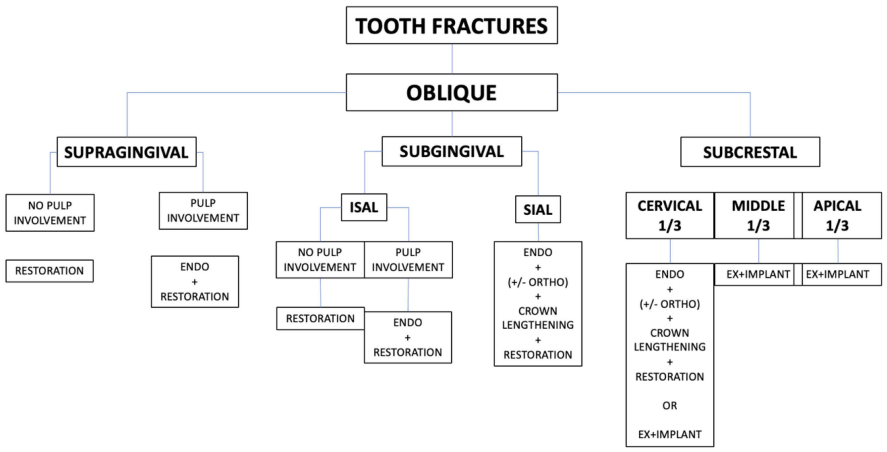
Furthermore, Giachetti et al. also support this procedure whenever it is possible to achieve a perfect margin [21].

Eichelsbacher et al. published a case series of 20 oblique fractures extending up to less than 1 mm from the osseous crest, treated with an adhesive approach [40]. Follow-up at 6, 12 and 24 months evaluated the clinical attachment level, bleeding on probing, the Gingival Index and the Plaque index, excluding the presence of gingival inflammation, recession or pockets. Periodontal disease was not detected in any of the participants [40].

Further evidence is still requested to support this restorative approach and clarify whether a subgingival direct/indirect adhesive restoration might differ from a conventional non-adhesive indirect restoration.

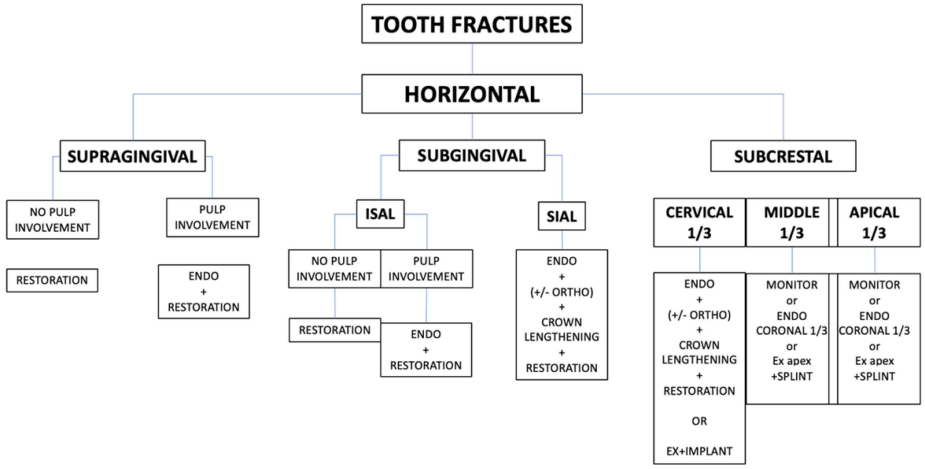
7. Conclusions

In dentistry, tooth fractures constitute one of the clinical conditions requiring timely and well-informed decision-making. Consequently, clinicians must have a comprehensive understanding of the diagnostic and therapeutic steps, which should be firmly grounded in the current scientific evidence. The proposal of a diagnostic pathway (Figure 10) that takes into account not only the impact on dental structure but also the periodontal involvement at different levels of such a lesion represents a valuable and more comprehensive tool for operators. All the possible treatment options must be meticulously considered for each specific clinical scenario, with the final decision contingent upon a thorough assessment of all the available clinical factors, including the subjective perspective of the patients.



(**a**)

Figure 10. *Cont.*



(**b**)

Figure 10. Flow-chart diagram for tooth fracture treatments: (**a**) horizontal fractures; (**b**) oblique fractures.

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