Regeneration, Reconstruction & Restoration *Hypothesis*

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A Clinical Decision Tree for Preserving versus Extracting a Compromised Tooth with Extensive Subgingival Caries or Crown Fractures

Neda Moslemi[a,b] , Elham Farhadi[c] , Mehdi Farhadi[d*]

[a] Dental Research Center, Dental Research Institute, Tehran University of Medical Sciences, Tehran, Iran; [b]Department of Periodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran; [c] Department of Restorative Dentistry, School of Dentistry, Arak University of Medical Sciences, Arak, Iran; [d] School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

***Corresponding authors:** Mehdi Farhadi, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran. **E-mail:** m-farhadi@student.tums.ac.ir; **Tel:** +98 912 924 9424

Submitted: 19 December, 2023**; Accepted:** 10 February, 2024**; Published Online:** 18 March, 2024 **; DOI:** *10.22037/rrr.v9.44150*

One of the most challenging issues in the field of dentistry is to decide whether to preserve or extract a compromised tooth with subgingival caries/crown fractures. Several patient-related factors (i.e. biological, behavioral, or financial factors), tooth-related factors (i.e. periodontal, endodontic, or restorative factors), and the role of the tooth in the overall treatment plan should be considered to make the most accurate decision. This article has focused on the decision-making process related to the management of compromised teeth with subgingival caries/crown fractures. Based on the current scientific evidence and clinical experience of the authors, an algorithm has been suggested to simplify this process of decision. In the first step, compromised teeth were classified as single-root or multi-root groups. "Crown-to-root ratio" (C/R ratio), and "apical extension of caries to the crestal bone" were considered the main clinical parameters in the decision-making process for single-root and multi-root teeth, respectively. We do not recommend restoring the compromised teeth if the C/R ratio is more than 1 (for single-root teeth) or if the extension of caries has reached the alveolar bone crest (for multi-root teeth). For maintainable single-root teeth, there are three treatment options to provide space for the re-establishment of supracrestal soft tissue attachment (previously named as biologic width) between the future restorative margin and underlying crestal bone. These approaches include: surgical crown lengthening (SCL), orthodontic forced eruption (OFE), and deep marginal elevation (DME). For multi-root teeth, SCL and DME are usually the procedures of choice. Multi-root teeth are not amenable to OFE due to the heavy orthodontic forces needed for extrusion. We also discussed the indications and limitations related to each treatment option. Further studies should be conducted to evaluate the external validity of this decision tree.

Keywords: Decision trees; Decision making; Tooth fractures; Dental caries; Tooth extraction.

1. Introduction

A compromised tooth is defined as a complex clinical scenario that results from structural, endodontic, or periodontal diseases, which impairs the functional or esthetic abilities of the tooth and needs some type of intervention to save it (1). The decision to save or extract a hopeless tooth is one of the most challenging issues in dentistry (2). The role of natural teeth in oral esthetics and functions is of great importance. Tooth extraction can significantly decrease quality of life and cause problems in speech and mastication (3). Dental implants are often a valuable treatment option when compromised teeth are extracted. However, implant therapy is not free of complications and may be accompanied by biologic and mechanical failures such as severe peri-implantitis and fixture/screw fractures (4). Evidence indicates that properly treated damaged teeth can have a higher survival rate than implants (5). In this respect, it is important to note that implants should not be considered as a replacement for teeth but as a solution to tooth loss. Since this is an irreversible process, it is crucial to have a detailed guide to make the right decision.

Cárcamo-España et al. in a literature review, generally, introduced factors that need to be considered in the decision-making process. These factors included patient and individual dentition factors. Patient's factors were classified into biological (systemic condition, family history, some needs that restrict oral hygiene, etc.), behavioral (such as poor oral hygiene, inadequate diet, parafunctional habits), and financial/personal (motivation, financial issues, availability of time, etc.) factors. Individual dentition factors were classified as periodontal, prosthetic, aesthetic, and restorative/endodontic factors (6). In recent years,

other few approaches have been developed to consider these factors in the decision-making process. These approaches have been offered in different forms: charts, decision trees, tables, and algorithmic diagrams (7-10). Although these studies provided valuable factors, useful in the decision-making process, none of them has focused on the individual clinical scenarios, in detail. Furthermore, among various types of compromised teeth, those with extensive caries/fractures are the most routine cases faced by dentists. Usually, dentists are able to restore the teeth with supragingival caries/fractures. However, the challenge arises when the extension of the caries/fractures line is below the gingival margin.

In this article, we have focused on this important topic, since no study was found to give a detailed and step-by-step decision-making algorithm for such compromised teeth with extensive caries/crown fractures.

2. Treatment options to preserve the teeth

Extensive caries or fractures in the compromised teeth are often associated with severe defects with subgingival margins. To restore such teeth, we need to employ techniques that result in "apical displacement of the supporting tissues" or "extrusion of the tooth", allowing access to the margin of caries/fractures, and providing sufficient space to create the supracrestal tissue attachment (STA) (11). STA, previously called "Biologic width" is defined as the established distance beginning at the most coronal part of the epithelial attachment and ending at the most apical part of the connective tissue attachment (12). This distance is approximately 2.04 mm in the average population (13). STA serves as the tooth's natural seal against diseases and infections (14). When the STA is violated, severe gingival inflammation develops, resulting in the formation of deep pockets or gingival recession in addition to a reduction in bone level (15). Furthermore, a ferrule effect of 1 or 2 mm is also required. The term "ferrule effect" refers to the metal collar that surrounds the dentine's parallel walls in a 360-degree circle and extends coronal to the preparation's shoulder. The outcome is an increase in the crown's resistance form due to the dentinal tooth structure's extension (16). Thus, to avoid adverse effects on the surrounding periodontal soft and hard tissues, the establishment of at least a 3-4 mm distance from the restorative margin to the alveolar crest is necessary (12).

Generally, there are three options for exposing the margin of caries/fractures to the supragingival area, in order to enhance the restorability of a compromised tooth. These options include 1) surgical crown lengthening (SCL), 2) orthodontic forced eruption (OFE), and 3) deep marginal elevation (DME) technique.

2.1. Surgical crown lengthening

Surgical crown lengthening (SCL) is a procedure in which the gingival tissue is displaced apically, with or without elimination of alveolar bone, to expose healthy tooth structure for restorative purposes and to prevent STA violation) (17). Frequently, SCL is accompanied by alveolar bone reduction. However, there are rare cases with subgingival and inaccessible margin of caries/fractures, but adequate distance from the alveolar bone (more than 4 mm). In such situations, SCL without crestal bone reduction or gingivectomy is indicated.

2.1.1. Indications of SCL

- If multiple neighboring teeth are involved (18);
- In the esthetic zone, if the teeth have delayed passive eruption;
- Compared with orthodontic forced eruption (OFE), SCL is faster and if patients do not accept a long duration of therapy, SCL is a better option (19);
- If the neighboring teeth are absent or do not provide sufficient orthodontic anchorage;
- In the esthetic zone, if the caries/fractures line is in the palatal;
- If the compromised tooth is present in the non-esthetic areas (18).

2.1.2. Contraindications of SCL

- If SCL will create unfavorable C/R ratio (more than 1);
- If there is a possibility of compromising the support of adjacent teeth (17);
- When only one tooth in the esthetic zone needs SCL (19);
- The presence of tooth/root proximity may result in limited access for clinicians during SCL (8).

2.1.3. Limitations of SCL

- Furcation/Flute: The furcation is a complex anatomical region. When the distance between the caries/fractures margin and furcation is Less than 4 mm; furcation may be involved during SCL. Furcation involvement presents significant challenges for the dentist in restorative and prosthodontic procedures (17). Flute shape tooth repair is one of the most difficult and complex perio/restorative procedures for dental practitioners (Figure 1.A) (20); the chance to perform SCL in such cases is highly dependent on the location of caries/fractures line (interproximal vs.

buccal/lingual) in relation with the furcation area. For mandibular molars, if the location of the caries/fractures margin is in the interproximal area, there is a chance to bypass the furcation area during SCL. The positive architecture of the alveolar bone can be achieved by shaping the radicular area of the buccal/lingual alveolar bone without involving the furcation area (Figure 1.B). However, this will not be the case where the margin of caries/fractures. is extended to the buccal/lingual area and you will need at least 4 mm distance from caries/fractures margin to furcation area to perform SCL. This scenario is not relevant for maxillary molars, since the furcation is present in the interproximal area as well as the buccal site. This is apparent that the longer the root trunk, the higher the possibility of maintaining the tooth;

- Fenestration and dehiscence: There are two types of cortical bone resorption: dehiscence, i.e. denudation of root surface, and fenestration, i.e. a bounded cortical resorption that leaves the marginal edge unaffected. In both cases, the elimination of alveolar bone during SCL may lead to more bone support loss around the root of the tooth and treatment failure (Figure 1.C) (21);
- The inadequate vestibular depth and attached gingiva (for distal wedge surgery) may result in complexities for flap design in SCL (Figures 2 and 3) (22);
- When the implant is adjacent to the tooth, SCL may lead to crestal bone resorption around the implant (Figure 4);
- When the fixed restoration is near the compromised tooth, the exposure of restoration margins may occur as a consequence of SCL (Figure 5).

Key point: The caries/fractures location in the interproximal area requires more supportive bone elimination during SCL (to provide positive architecture) compared to the buccal or lingual caries/fractures' location (Figure 6).

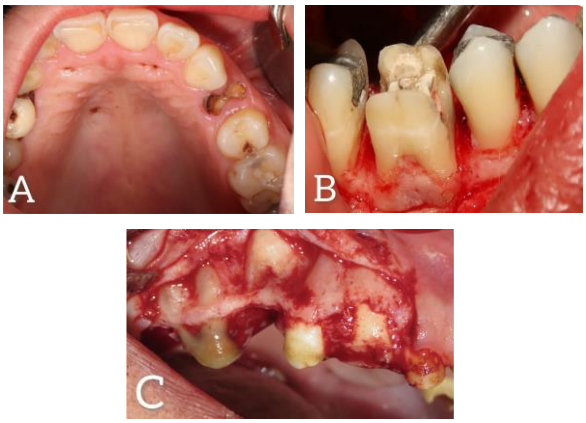

Figure 1. Flute shape left maxillary first premolar (A), the location of the caries is far from the furcation area (B), and fenestration (C).

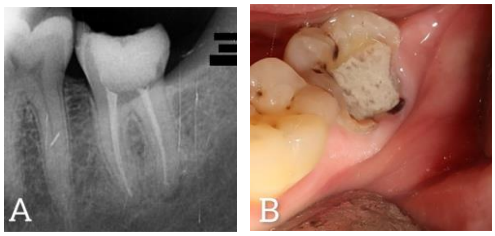

Figure 2. The inadequate vestibular depth in the distal of the second molar. Radiographic view (A) and clinical view (B).

Figure 3. The adequate attached gingiva for distal wedge surgery.

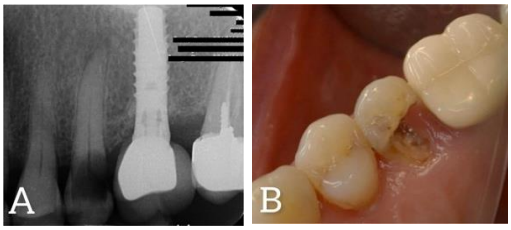

Figure 4. Implant adjacent to the compromised tooth. Radiographic view (A) and clinical view (B).

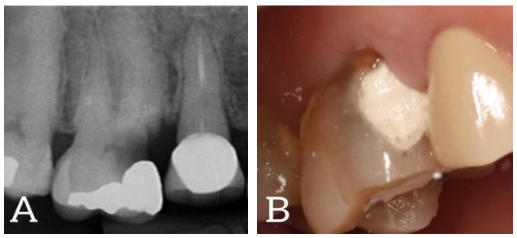

Figure 5. Fixed restoration adjacent to the compromised tooth. Radiographic view (A) and clinical view (B).

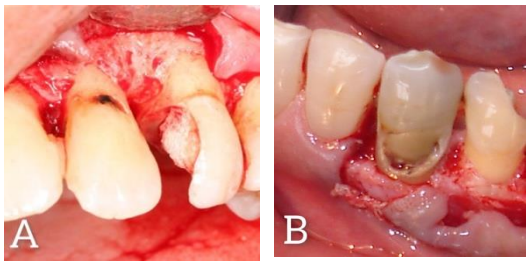

Figure 6. Caries location in the interproximal area (A) and caries location in the buccal area (B).

Case Report: A 36-year-old woman presented with extensive caries in left maxillary incisors and altered passive eruption. By SCL, the height of the tooth crown increased for proper restoration and the patient's aesthetic problem (because of altered passive eruption) was solved (Figures 7A and B).

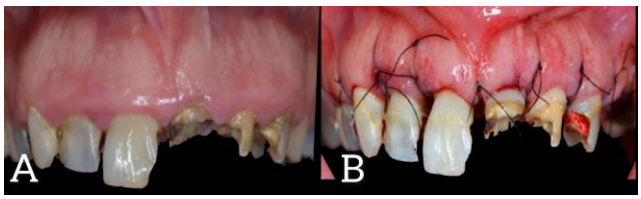

Figure 7. Before surgical crown lengthening (A), and after (B).

2.2. Orthodontic forced eruption

Orthodontic forced eruption (OFE) is a less invasive treatment method for maintaining the compromised tooth and its periodontal structure by orthodontic extrusion of the tooth and is used to expose the margin of the caries/ fractures into the supragingival area for restorative purposes (23). OFE may be performed slowly or rapidly. If the tooth erupts rapidly, in the absence of the alveolar bone for a while, a circumferential fiberotomy may be carried out to prevent bone following the erupted tooth. However, if OFE is performed slowly, the bone and soft tissue follow the tooth, and following the accomplishment of OFE, crown lengthening may be required to return the bone level to its primary state and correct the soft tissue leveling (19). OFE is usually used for single-root teeth. One of the main advantages of OFE compared to SCL procedure is the lack of need for alveolar bone resective procedures.

2.2.1. Indications for OFE

- This is particularly beneficial when only one compromised tooth in the esthetic zone is required to be saved (18);
- If the extent of bone resection predicted during SCL will considerably damage the periodontal attachments of adjacent teeth;
- If the gingival levels are in ideal condition and the expected apical positioning of the gingival margins on the affected and adjacent tooth(s) during SCL will result in uneven gingival contours in esthetic areas of the mouth or expose the prosthetic crown margins on adjacent teeth;
- If the expected C/R ratio achieved with SCL is insufficient (17).

2.2.2. Contraindications of OFE

- Inability to carry out orthodontic extrusion due to insufficient anchorage;
- When root taper is narrow in affected tooth/teeth;
- The patient's refusal of orthodontic treatment;
- The affected tooth(s) buccal gingival contour lies coronally at the ideal level of desire (17).

Case Report: A 14-year-old man presented with trauma in the maxillary left central incisor. After root canal treatment, the fractured edge of the tooth was removed from under the bone crest by rapid OFE. Then the tooth was restored (Figures 8A and B).

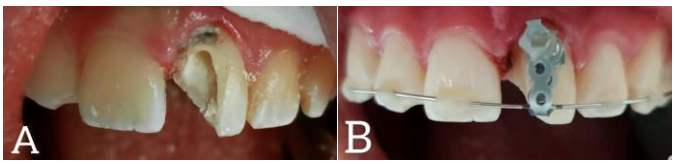

Figure 8. Before rapid orthodontic forced eruption (A), and after (B).

Case Report: A 22-year-old man presented with trauma in the maxillary left central incisor. In this case, after slow OFE, crown lengthening was performed to improve gingival level status (Figures 9A, B, and C).

2.3. Deep margin elevation

In deep margin elevation (DME) technique, restorative materials (such as composite resin and resin-modified glass ionomer) are employed to elevate the tooth margins into an equigingival or supragingival position (24). Minimally invasive DME can sometimes replace invasive SCL. Compared to SCL, some studies indicated that in certain situations, DME is a better option for subgingival cavities. The materials are not able to create an ideal connective tissue attachment. In addition, reconstruction of normal periodontal attachment is not provided by DME. However, DME creates a different STA, mostly

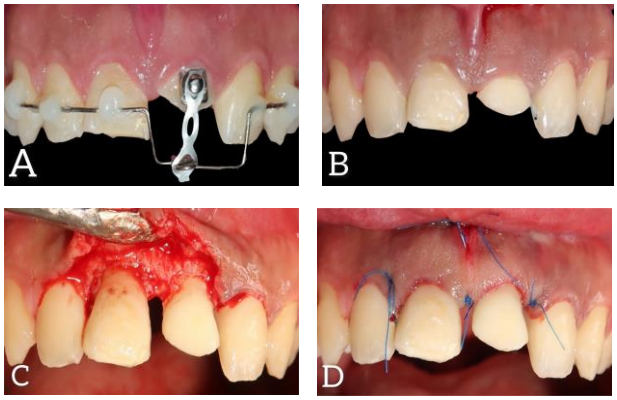

Figure 9. Before slow orthodontic forced eruption (A), after (B), and crown lengthening after slow orthodontic forced eruption (C).

composed of a slight connective attachment on the dentin underneath the material and a lengthy junctional epithelium (11,25).

2.3.1. Indications of DME

- When surgical procedures are not feasible;
- Field isolation ability;
- Excellent matrix sealing of the cervical margin.

2.3.2. Contraindications o DME

- Damage below the junctional epithelium;
- Less than 2 mm distance between damage margin and bone;
- Poor oral hygiene (11).

Case Report: A 33-year-old male was presented for restoration of endodontically treated right mandibular first and second molars. In this case, the SCL had limits because when the roots are short, bone removal may result in an unfavorable crown/root ratio or furcation exposure. DME was selected as the appropriate treatment plan (Figure 10) (26).

Figure 10. Clinical view of mandibular second molar before treatment (A), clinical view of right mandibular first molar before treatment (B), radiographic view of right mandibular first and second molars before treatment (C), and clinical view of right mandibular first and second molars after deep margin elevation (D).

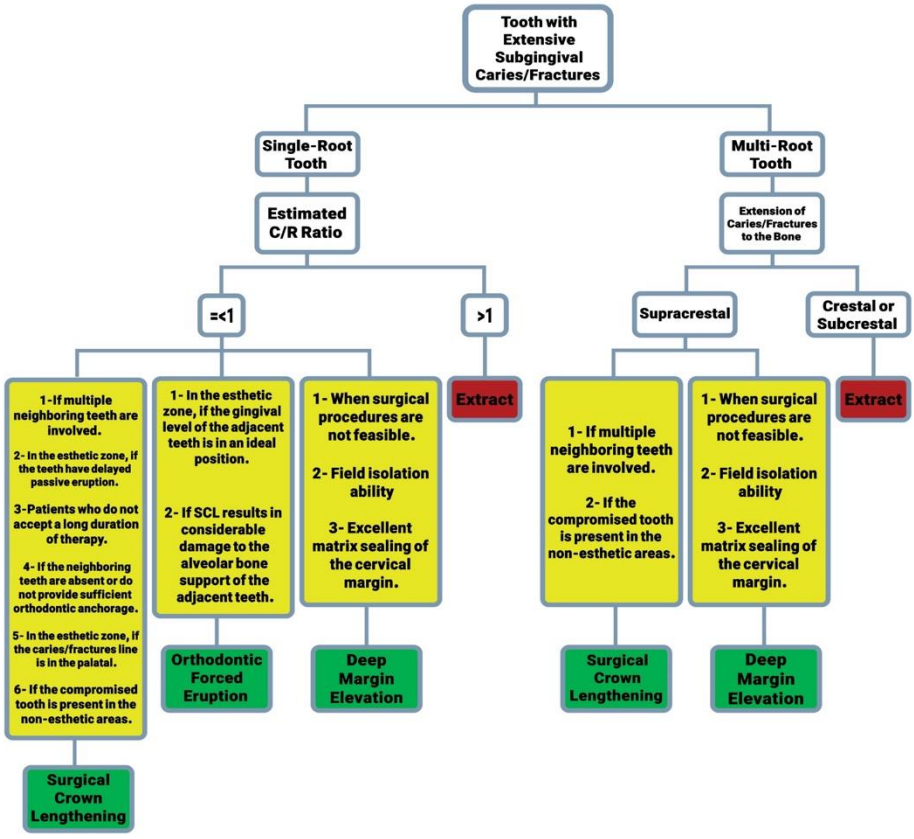

Figure 11. Decision-making tree (This may not be applicable if there is any contraindications or limitation factor. For better understanding please refer to the article.)

3. Decision-making tree

lthough SCL and DME techniques are applicable for all types of teeth, usually OFE is not feasible in multi-root teeth. Displacement of the multi-root teeth needs heavy orthodontic forces which are not usually possible by using dental anchorage. Therefore, due to the different possible treatment approaches between single-root and multiple-root teeth, we decided to classify the teeth into these tooth types. Then, in each tooth type, based on specific clinical parameters, the decision has been made regarding the preservation or extraction of the compromised tooth, and treatment approaches have been suggested (Figure 11).

3.1.Single-root tooth

In the extension of caries/fractures to the crestal bone, single-root compromised teeth (with subgingival caries/fractures) have a greater chance for preservation compared to multi-root teeth; since OFE can be a further treatment solution in single-root teeth especially where caries/fractures have been extended to the sub-crestal area.

The crown-to-root (C/R) ratio is an important criterion that has been used in many decision-making approaches to determine whether teeth can be restored and preserved successfully (6-8). This ratio is described as the radiographically determined physical relationship between the alveolar bone-covered part of the tooth and the remaining part of the tooth (7). Focusing on the field of restorative dentistry, it is speculated that teeth with unfavorable C/R ratio may not act as ideal abutment teeth. Single-root teeth with C/R ratio of more than 1 are more prone to tooth mobility and they may lead to progressive mobility and persistent clinical signs of pain and tenderness during function, as a result of secondary trauma from occlusion. Furthermore, C/R=1 is considered the minimum acceptable ratio in cases with healthy periodontium and controlled occlusion (8). However, the C/R ratio of more than 1 may not induce increased mobility in teeth with two or more roots (multi-root teeth). Therefore, the decision-making process in multi-root teeth should not be rely on the C/R ratio.

Thus, in this article, we have proposed C/R ratio as the clinical parameter to help dentists make a decision in compromised single-root teeth. If C/R ratio is higher than 1, the tooth should be extracted (Figure 12). But if C/R ratio is less than or equal to 1, the tooth can be preserved (Figure 13) (7). Our decision-making tree suggests SCL, OFE, and DME to preserve the teeth.

3.2.Multi-root tooth

The increased surface area of the multi-root teeth in the bone results in decreased mobility of these teeth, even if the C/R ratio is more than 1. Therefore, this criteria might not be a good indicator in the decision-making process of multi-root teeth. On the other hand, SCL is the most common approach for the re-establishment of supracrestal soft tissue attachment (biologic width) and providing space for the restorative margin in multi-root teeth. However, due to considerable damage and loss of supporting bone of the adjacent teeth, usually, SCL is not indicated if the apical extension of caries/fractures has been reached to the crestal bone (8,27). Hence, this important criteria can be used as an appropriate reference for saving or extracting a multi-root tooth.

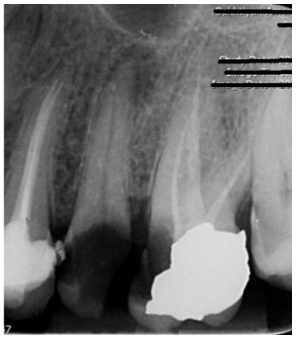

Figure 12. Maxillary second premolar with C/R >= 1.

Figure 13. Mandibular second premolar with C/R < 1.

For years, root resection was the ideal treatment for the subcrestal spread of caries in multi-root teeth (28,29). However, some studies suggested that the survival rate of teeth resected due to non-periodontal issues (e.g. tooth fractures and dental caries) is low (30). Furthermore, the root resection procedure is often accompanied by significant alveolar bone loss to provide access to the questioned root and to remove it. This significant and irreversible resective procedure can jeopardize the possibility of future implant placement. Therefore, with the advent of implant therapy, extraction of such teeth and replacing them with dental implants is more advocated (Figure 14A). If caries or fractures extend supracrestally, the tooth might be preserved (Figure 14B). Recently, DME has been proposed as a valuable alternative and less-invasive approach for the management of compromised multi-root teeth. Bresser et al. in a clinical study in a period of 12 years, evaluated the clinical performance of 197 indirect restorations with DME in the posterior region. The overall

survival rate was 95.9%, and five of the eight failures were related to recurrent proximal caries (31).
In another clinical study with long-term follow-ups (from 6 to 21 years), Dietschi et al. observed no secondary caries in 25 cases with posterior compromised teeth, after the application of DME (32).

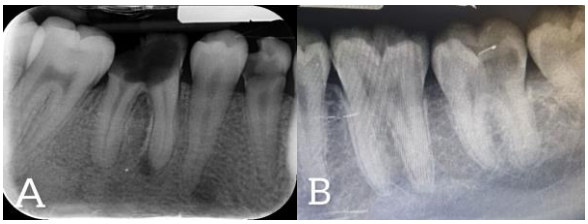

Figure 14. Mandibular first molar with crestal caries (A), and mandibular second molar with supracrestal caries (B).

Key point: Sometimes the compromised tooth must be preserved in any way and avoid extraction. For example, while the patient taking bisphosphonates, several guidelines recommend avoiding tooth extraction (Figure 15) (33,34).
Also, in adolescents with traumatized tooth(s), even if future extraction is scheduled, traumatized teeth can continue to function and keep aesthetics in the interim. Maintaining these teeth in the absence of infection may allow the alveolar processes to continue developing normally, which might be adversely affected by early tooth loss (Figure 16) (35).

Figure 15. Compromised teeth in patient taking bisphosphonates.

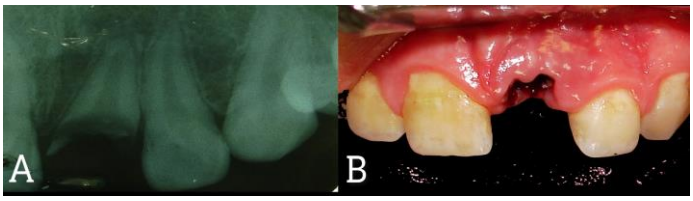

Figure 16. A 13 years old patient with traumatized tooth. Radiographic view (A) and clinical view (B).

4. Conclusion

When the teeth compromise due to caries or fractures, the decision-making process about this teeth treatment is challenging and many factors influencing this process must be considered. The tree suggested in this article can be used by dentists as a decision help for the preservation or extraction of compromised teeth with subgingival caries/fractures. Future studies need to be conducted to evaluate the validity of the decision tree proposed by the authors.

Acknowledgment

None.

Authors' contributions

Neda Moslemi: Conceptualization, Writing-Review & Editing, Supervision
Elham Farhadi: Writing - Review & Editing
Mehdi Farhadi: Writing - Original Draft, Project administration

Conflicts of interest

The authors declare that they have no conflicts of interest related to this article.

Funding/support

None.

ORCID

Neda Moslemi https://orcid.org/0000-0002-2616-2732
Elham Farhadi https://orcid.org/0000-0002-2552-6223
Mehdi Farhadi https://orcid.org/0009-0005-1651-5935

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Please cite this paper as: Moslemi N, Farhadi E, Farhadi M. A Clinical Decision Tree for Preserving versus Extracting a Compromised Tooth with Extensive Subgingival Caries or Crown Fractures. Journal of "Regeneration, Reconstruction & Restoration"(Triple R). 2024; Volume 9 : e1. Doi: 10.22037/rrr.v9.44150