Surgical Extrusion: A Simplified Esthetic Method of Treating Non-Restorable Teeth. Rationale and Case Report.

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Abstract

The restoration of teeth which have been compromised by loss of crown and radicular structure due to caries, fractures, root resorption or iatrogenic lesions, could result in the violation of the biological width with consequent gingival inflammation, loss of attachment and alveolar bone loss. It is essential in these cases to obtain a portion of the tooth structure that is adequate to allow restoration that respects the biological width.

This article presents two cases in which the tooth structure of the compromised teeth was gained with Surgical Extrusion.

The procedure allows in a single step to extrude the root, thereby shifting the compromised site from sub gingival to supra gingival. This allows adequate space to re-establish the biological width, while simplifying and speeding up the restorative procedures.

The combination of this fast and reliable procedure with modern tooth preparation, modern adhesive techniques and the latest generation of restorative material, is a perfect match with the philosophy of "minimally invasive procedures", with undeniable advantages for the patients.

INTRODUCTION

The restoration of teeth which have been compromised due to the extensive loss of tooth structure caused by caries, fracture, root reabsorption or iatrogenic lesions, can result in the violation of the biological width (1, 2) meaning the combination of the junctional epithelium (0,97 mm on average) and the attachment of the supra-crestal fibres (1,07 on average), with consequent gingival inflammation, loss of both attachment and alveolar bone (3-7).

These cases have the following restorative problems:

- tooth isolation difficulties (8) for effective adhesive procedures
- the lack of adequate residual tooth structure for the retention of the restorative procedures
- placement of the restorative margin too deep into the periodontium.

To enable a restoration to be placed respecting the integrity of the biological width it is necessary to carry out procedures that create sufficient sound tooth structure

To this end various types of treatment have been proposed:

- crown lengthening by gingivectomy or apical positioned flap with or without osteotomy / osteoplasty (14)
- orthodontic extrusion (15-19)
- surgical root extrusion (20, 21)
- tooth extraction and replacement with a fixed prosthesis or osseointegrated implant (22, 23)

The most used treatment requires a surgical approach which often involves osteotomy, osteoplasty (24) and successive apical positioning of the flap (Fig. 1). This procedure is not, however, without discomfort and side effects for the patient (25) (Tab. 1).

An alternative to the described techniques is **surgical extrusion** also named intra-alveolar transplantation. This technique was first described by Tegsjo in 1978 (20) and was related to cases of tooth fracture in the anterior zone, especially in young patients. This technique is based on the biological fundamentals of the healing process following the re-implantation of teeth after avulsion (44, 45) and auto transplantation (46, 47).

This one step technique allows us to extrude the root by displacing the compromised portion from the subgingival position to the supragingival area re-establishing adequate space for the biological width and, at the same time, simplifying and making the restorative procedure more reliable (Fig. 4). This is done in a simple way with reduced operative time and cost.
This technique is particularly indicated in all those cases where the tooth is considered condemned to extraction (48) and could include all the cases where tooth structure has been lost in the area of the biological width due to crown-root fractures, caries, cervical root resorption and previous incongruous restorative procedures. Surgical extrusion could be used to delay the extraction of extremely compromised teeth, especially in young patients who still have a lot of residual growth to complete.

INDICATIONS

Surgical extrusion could be used in the following situation:

- crown-root fractures (this represents about 5% of all trauma to teeth)
- subgingival caries
- cervical root resorption (49)
- large radicular perforations of the coronal third of the root where other therapeutic solutions have failed
- incongruous prosthetic preparations that violate the biological width

1. In our experience this technique can be used as a treatment alternative for clinical crown lengthening and orthodontic extrusion. It is fundamental to inform the patient of the risk, even if minimal, of root fracture during the luxation procedure which inevitably will result in extraction of the tooth. Only then can this treatment solution, which is minimally invasive, with a short completion time and contained cost, be offered to the patient (Fig. 5).

CONTRAINDICATIONS

The contraindications are relatively few and can be subdivided in:

relative contraindications:

- presence of a high risk of root fracture during the luxation of the tooth such as in the case of narrow or curved roots (50) or a vertical root fracture that has progressed into the depth of the alveolar bone.

- presence of a crown root ratio equal or less than 1:1 (caries or fracture that extends deeply in the periodontium in the presence of a short root). In this cases the total alveolar bone support should be considered more the crown tooth ratio (30) and the presence of para-function, the functional role of the tooth (es. the canine) and the occlusal scheme of the patient (eg. severe overbite situation).

absolute contraindications:

- presence of anchylosed root
- risk of exposing the furcation (50-53)
- presence of systemic condition that controindicate surgery
- presence of long term biphosphonates therapy (56)

The surgical extrusion procedure is easier in the upper arch due to the lower bone density, while in the lower arch it can be more difficult and complex. This situation raises the risk of root fracture, especially in the presence of thin roots, and increases the incidence of damage to the cells of the periodontal ligament.

OPERATIVE PROTOCOL

The protocol foresees an operative sequence which can be outlined in the following steps:

1. Anestesia
2. Caries removal
3. Fiberotomy
4. Mobilization and luxation
5. Extrusion
6. Stabilization
7. Endodontic and restorative treatments
8. Provisional
9. Finalization

For the explanation of the steps, please refer to the discussion.

Case presentation 1

A 53-year-old male patient attended our clinic after a long period during which he had no dental treatment. Tooth 2.5 had been totally destroyed for a long time, due to caries (case 1, 1). The patient wanted to extract the tooth. However, once proposed, accepted a treatment plan to surgically extrude the tooth and restore it with a composite overlay. At the successive appointment, surgical extrusion was performed, after careful luxation was done with particular attention due to the accentuated curvature of the root (case 1, 2). At the occlusal level, part of the extruded tooth was reduced to avoid any contact whatsoever, and a single suture was placed (case 1, 3). The patient was dismissed with instructions to chew on the opposite side and rinse regularly with chlorhexidine. After two weeks, only slight mobility was encountered and so endodontic treatment was performed. Forty-five days after the extrusion tooth mobility was almost normal and after rubber dam isolation an adhesive build up was done (case 1, 4 - 6). At the same appointment, a definitive impression was

taken. The patient was dismissed with a provisional made from a light cured material (case 1, 7). After 10 days the composite inlay (case 1, 8). was cemented (case 1, 9). At the checkup the following week, the patient complained of soreness when biting on hard food. At successive checkups, the patient reported that the previous discomfort had gradually abated and after 10 days was resolved completely (case 1, 10 - 11). Radiographically control,18 months after extrusion, one can appreciate the correct formation of the bone peaks and the periodontal probing depth measured 1,5/2 mm (case 1, 13).

Case presentation 2

The patient, age 45 (case 2, 01), attended our practice after having been for consultations with other clinician.

Examination revealed the presence of a fixed prosthesis in metal-ceramic from tooth 12 to 22 (case 2, 03 - 04). Radiographic examination revealed severe coronal destruction, due to caries, under the prosthetic restorations of the lateral incisors (case 2, 05). The coronal destruction of tooth 12 was particularly severe and the tooth was also distally displaced making contact with tooth 13. The patient informed us that she had already received treatment proposals from other colleagues. Some of the treatment options foresaw extraction of the lateral incisors with implant placement or orthodontic extrusion (as the smile line was high, surgical lengthening of the clinical crown, on its own, was contraindicated) followed by surgical repositioning of the periodontal tissues. The patient expressed the wish not to extract the lateral incisors and also not to undergo orthodontic treatment and asked for an alternative treatment. We showed the patient the surgical extrusion technique, careful to explain the risk of root fracture during the extrusive manoeuvre, and she decided to accept this treatment plan. At the first appointment, the fixed prosthesis was removed (case 2, 06) and an initial removal of the damaged tissue on the lateral incisors was carried out (case 2, 07 - 08). Successively, as it was possible to isolate the roots with rubber dam, endodontic re-treatment of the four incisors was carried out. At a new appointment, after administering local anesthesia, the two lateral incisors were delicately luxated and partially extracted (case 2, 09 - 10). Sutures were placed mesially and distally for each tooth. A wooden wedge was temporarily placed between the canine and tooth 12 to position it correctly in the edentulous space (case 2, 11) and both teeth were stabilized with a small amount of composite to their respective adjacent canine (case 2, 13). The patient was dismissed with the old prosthesis cemented temporarily with the lingual part having been preventively removed before (case 2, 14 - 16). No antibiotics were prescribed, only daily mouth rinses with 0,2% chlorhexidine mouthwash. The sutures were taken out after a week and ten days later the composite splint was removed as well (case 2, 17), at which time a resin provisional prosthesis was relined and cemented. Three weeks after the extrusion, the abutments were constructed after measuring both height and width of the residual structure (case 2, 20 - 24). It was assessed that the latter was sufficient to support the stress connected to the guiding function in protrusive and lateral movement, so it was decided not to use any posts for the reconstructions (case 2, 25 - 26). At this stage, on request of the patient, to improve the smile-line and the progression of the labial corridors, a mock up in resin that extended to the second upper premolars was fabricated (case 2, 27 - 30). The case was finalized with four lithium di-silicate crowns on the incisors, two labial veneers on 13 and 23, and four additional buccal veneers on the four premolars (case 2, 31 - 34).

The crowns were cemented with a self-adhesive cement while the veneers were adhesively cemented following rubber dam isolation (case 2, 35 - 40). At the successive clinical and radiographic checks (case 2, 41 - 46), the periodontal tissue was in optimum health with maximum

probing depths of 2,5mm. This case presents a follow-up of 2.5 years with good functional and esthetic integration of the treated teeth.

DISCUSSION

The most used treatment for the recovery of severely compromised teeth requires a surgical approach which often involves osteotomy, osteoplasty (24) and successive apical positioning of the flap (Fig. 1). This procedure is not, however, without discomfort and side effects for the patient (25) (Tab. 1).

If carried out in the esthetic zone, it requires a long period of time for stabilization and maturation of the tissues (26, 27). Furthermore, when it is carried out on single teeth in the anterior zone in the presence of a high smile line, surgery on its own will result in an esthetically unacceptable gingival asymmetry. For these cases, orthodontic extrusion of the tooth is more indicated (18, 19, 28) which, however, is almost always accompanied by extrusion of the periodontal tissues (Fig. 2) that should then be surgically repositioned. In alternative, during the orthodontic phase, repeated fiberotomies should be performed (29) to limit or prevent the extrusion of the periodontal tissues. The scope of these procedures is to avoid successive surgical intervention. Each session of fiberotomy implies following administration of local anaesthesia, foresees the incision of the periodontal fibres at the gingival sulcus level and successively the tooth must be stabilized post-orthodontically stabilization to avoid re-intrusion.

The advantages of using the orthodontic technique of tooth extrusion are the reduced negative aesthetic impact and the reduced alteration of the final crown to root ratio (30).

The negative aspects of the orthodontic phase are represented by longer treatment time, esthetic and functional discomfort during the extrusion phase, increased costs and exposition of the narrower section of the root that has to be managed during the restorative phase (Fig. 3).

The cases where the tooth to be extruded is particularly compromised and it is not possible to position an orthodontic bracket, one has to resort to intra-canal anchorage to carry out the extrusion (31). This situation complicates the procedure especially if the tooth still requires endodontic treatment and the destruction of the crown makes it difficult, if not impossible, to place the rubber dam for isolation.

Extrusion times are dependent on the type of used force used and generally it takes around 5-6 weeks (32). Eight to 10 weeks of stabilization are then required to avoid re-intrusion of the root (32, 33, 34, 17, 35).

In the case where one wants to avoid extrusion of the periodontal tissues and therefore the successive surgical re-positioning procedure, the fiberotomy has to be carried out repeatedly (generally three /four times) at weekly intervals (29).

If tooth extraction is performed, the placement of an osseointegrated implant to replace the missing tooth is considered by according to some authors (36) the gold standard.

The placement of an implant is a procedure, however, that is not without discomfort and problems (36) namely:

- surgical discomfort

- early or late surgical complications (37)
- a positive aesthetic outcome is difficult to achieve with a low level of predictability (operator dependent) (38, 39)
- a provisional crown in the aesthetic zone (40) cannot be placed in cases with a low insertion torque
- component problems (screw loosening, fracture, etc.) (37)
- implant fracture (41)
- peri-implantitis risk (42, 43)
- enormous product variation with problems in the case of re-treatment

An alternative to the described techniques is **surgical extrusion**. The technique if applied with attention to selected cases is a simple, fast and successful procedure with a survival rate that is, in time, comparable with implants (21, 50, 63, 65).
The simplicity of the procedure is one of the fundamental aspects of this technique that makes it repeatable and not just for exclusive use by expert operators.

The protocol foresees an operative sequence which can be outlined in the following steps:

1. **Anesthesia**: intra-ligamental anesthesia is not recommended to avoid causing ischemia of the periodontium (52).
2. **Caries removal**: the removal of tooth structure damaged by caries must be carefully realized before mobilization of the tooth. This point underlines how essential it is to make the correct diagnosis so as to avoid that after the extrusion one ends up once again with sub-gingival margins after the cleaning.
3. **Fiberotomy:** a sharp thin blade is used to penetrate deeply into the periodontal ligament (66). This procedure has the function of reducing the traumatic component during the successive luxation carried out with elevators and forceps.
4. **Mobilization and luxation:** this must be done with a delicate manoeuvre paying attention to the positioning of the elevator and forceps. Chung et al., in 2010, states that to avoid damaging the cells on the root surface with consequent loss of bone at the marginal level, the forceps must be placed at the level of the cement-enamel junction (66). On the basis of these indications one has to pay particular attention to all the luxation procedures to cause the least amount of damage possible to the surface cells of the root. The coronal part, which suffers the most trauma during this procedure, will in any case be moved to a supra-gingival level, therefore in fact minimizing the risk of marginal bone loss (48). In some cases, to have an improved grip with forceps, it is possible to make a small marginal incision with or without a releasing incision.
5. **Extrusion:** the amount of extrusion depends on the depth of the lesion, the amount of residual tooth structure, and the type of restoration planned. Caliscan et al., in 1999 (52), reported from a clinical study of 20 cases that the average extrusion was 4,25 mm. Elkadem (54) from a revision of the literature reported an average value of 4,5 mm. In the case where one proceeds to do a traditional restoration with a post and full coverage crown, Juloski et al. (13), in a recent revision of the literature, states that the distance between the crown margin and the bone crest should be at least 3 mm. One has to add a further 1,5 mm of structure to this measurement to have an adequate ferule effect. In total, for this type of restoration, it would therefore be necessary to have at least 4,5mm

of tooth structure coronal to the bone crest. (13, 67). Every time the residual coronal tooth structure makes it possible to do a bonded partial restoration (either onlay or overlay), the amount of root to extrude would only be the minimum amount necessary to enable the correct rubber dam isolation of the operative field so as to carry out the bonding correctly. In this case, carrying out an adhesive buildup and bonding of the restoration in composite or ceramic, one avoids the destruction of the cervical structure of the tooth, which instead occurs with the preparation for a full crown. One must bear in mind that, in most cases, having lost the roof of the pulp chamber and often the marginal crest, the only remaining structure of the endodontically treated tooth, offering any resistance to fracture, is represented by the cervical dentine (68, 69). This safeguard for maintaining the strength of the endodontically treated tooth is imperative. When adhesive cements were not yet available, one had to resort to the use of the full crown which necessitated a retentive preparation, that is with a conical connection. In these cases the absence of an adequate amount of cervical dentine, essential for the ferule effect, obliged one to perform a surgical lengthening of the clinical crown to recover this part. At this point, however, the preparation for a full crown involves destroying a substantial amount of the cervical dentine, laboriously recovered previously. Currently, with the available adhesive technique, minimally invasive preparations (70, 71) and modern restorative materials, residual cervical structure can be preserved by the bonding of an onlay or overlay. (case 1). Adhesively retained partial restorations don't need to remove sound tooth structure purely for establishing resistance and retention form (72). The preparation for an adhesive overlay foresees that the lingual wall is reduced with a butt joint preparation without reducing the thickness. As regards to the vestibular wall, once the occlusal portion is reduced to allow sufficient restorative space, it is sufficient to provide a minimally bevelled preparation to improve the esthetic integration of the margins. The extension and the thickness of this vestibular bevel will depend on the level of the discolouration of the abutment, on the material used for the restoration (composite or ceramic) and on the visibility of the tooth in the arch. The surgical extrusion of the tooth exposes a section of the root with a reduced diameter. In some cases it is possible for one to do a minimum, or even no preparation, of the tooth core so that the slight over-contouring created by the restorative material compensates for the reduced root diameter. This situation is particularly useful for cases where there is discolouration of the root that has to be covered by the restorative material. The advantage of bonded partial restoration is huge from both a biological point of view, because the tooth preparation is completely extra-gingival, as well as biomechanically, because the walls of the tooth are not reduced in thickness (Fig. 7). Therefore, the necessity to create the ferule effect can be completely eliminated, as it can only be effective in combination with a retentive preparation design (conical connection). It is more than fifteen years that this type of therapeutic approach has completely revolutionized our way of treating compromised teeth, so much so that since then we hardly ever restore teeth with posts and full crowns (25, 73). The reduced extrusion of the root offers the advantage of a smaller reduction of the diameter of the emerging root (less restorative problems) and a minor alteration of the root/crown ratio. In the case of teeth in the anterior zone, the recovery of sufficient tooth structure by surgical extrusion associated with the adhesive technique and the latest generation ceramic materials allows for a minimally invasive preparation of the abutment. The amount of tooth

structure saved in this way often allows the restoration of the abutment without the use of posts (case 2).

6. **Stabilization:** For some authors, it is possible to execute the stabilization simply by mesial and distal suture. This would allow an effective functional stimulation which would obtain a correct reorganization of the periodontal ligament fibers. This precaution seems to drastically reduce the risk of ankylosis (46). Caliskan (52) says that the splint for a week is sufficient for the primary stabilization and the initial organization of the coagulum (44, 45, 52, 61). Keep the splint for more than 3 weeks time, increase the risk of ankylosis (61). We prefer, based on our experience, to use a composite splint to the adjacent teeth for a period of no longer than two weeks. The purpose of this is to avoid root dislocation, especially in cases of notable discrepancies between the root and the socket, or when the root has to be centered in the interdental space. This helps us prevent that the patient, who may not always respect the correct instructions for home care, is able to interfere with the initial stabilization phase. The patient is dismissed with instructions to not chew on the side of the extruded tooth and to rinse daily with 0,2% chlorhexidine for a week. Normally we do not prescribe antibiotics, even though this is suggested in literature by many authors (48, 52, 58, 73). In our opinion, a careful surgical procedure, the immediate formation of a good coagulum (75), and regular rinsing with chlorhexidine are sufficient to avoid any possible alveolar infection. The sutures are removed after a week and the patient is instructed to start brushing with a soft brush.
7. **Endodontic and restorative treatments:** if the tooth has not been treated or has to be endodontically re-treated, the decision to carry out endodontic treatment before or after extrusion then depends on the possibility of isolating the tooth with rubber dam. If the tooth can be isolated then the treatment can be performed before extrusion, if not it must be postponed to a time following the extrusion (57). In cases where it is impossible to position the dental dam, it is preferable to postpone endodontic treatment until after the extrusion phase. In this way it will be much simpler to position the rubber dam, avoiding any risk of contamination during endodontic manoeuvres. After 2/3 weeks (53, 66, 73) the root has adequate stability for an eventual endodontic treatment or re-treatment and restoration of the abutment. In situations with a very tapered root, such as in the case of central incisors, much space will be created between the root and the socket after extrusion. This results in strong consequential mobility of the root for a purely geometrical reason. In these cases we prefer to increase the splinting time for two extra weeks (for a total of 4/5 weeks) before performing endodontic and restorative manoeuvres. The authors recommend to implement the procedures restorative after the tooth has achieved a lower than grade 2 mobility.
8. **Provisional:** in the case of the esthetic zone it is essential to place a provisional as soon as possible, such as a thermo plastic Essix appliance with a resin tooth fixed inside, or a provisional Maryland Bridge, or even a resin tooth fixed with a wire and orthodontic brackets to adjacent teeth (Fig. 8). It is fundamental that during the first three weeks the extruded tooth is not exposed to excessive functional loading. In our experience, it is possible to start functional loading of the extruded tooth with a provisional restoration, 6 weeks after the procedure.
9. **Finalization:** after 45 days there is a definite reduction in the mobility of the tooth due to the fact that the periodontal ligament has reacquired its characteristics (76). Kim (73) radiographically observed that two months after surgical extrusion there was the

apposition of periapical new bone. In our clinical experience, 60 days after the procedure, it is possible to finalize the case with a direct or indirect restoration.

Advantages

For the clinician:

17. Speed of execution: a short single appointment is usually sufficient to carry out the partial extraction and successive provisional splinting of the tooth.
18. Simple execution: the procedure does not require particular knowledge, ability or experience as required for other techniques (57). The surgical extrusion must nevertheless be done gently and with a great deal of caution to reduce the risk of root fracture to a minimum during its execution.
19. Reduction of time needed to finalize the restoration: the case can be finalized after about eight weeks.
20. Direct and immediate control of the height of the extruded tooth in relation to the periodontal tissues, which do not change their position during the healing period.
21. Conservation of the architecture of the periodontal tissue on the adjacent teeth as well: the gingival scalloping remains unchanged even during the early healing phase. The periodontal support of the nearby teeth is not subject to any alteration. No risk of furcation exposure, creating inverse architecture or margins exposure of adjacent teeth.
22. Possibility to directly inspect the root in the case of a suspected cracked root (58).
23. Possibility to rotate the root to facilitate the restorative procedure. In the case of a lingual fracture a rotation of 180° could reduce the height of extrusion if the labial gingival scallop is more apical than the lingual one (57, 58).
24. Low incidence of failure: the real failure risk is fracture of the root during the extrusive process (tab. 2).
25. Contained costs for the procedure.
26. Tooth recovery is more manageable even in cases where the tooth crown is destroyed. When we are faced with teeth which have lost all their coronal characteristics, in the case of orthodontic extrusion, intra-canal retention should be placed to apply traction (31). If the tooth requires endodontic treatment or re-treatment, isolating the working area becomes the major problem. Using the surgical extrusion technique this problem does not arise because one can mobilize the root immediately without intra-canal anchorage and the endodontic treatment or re-treatment would be delayed for three weeks, after which the tooth is stable and the working area can be ideally isolated.
27. Following surgical extrusion, bone is regenerated apically to the root and this could prove to be useful in the future if an immediate post extraction implant in that site should become necessary. In this way, an increased primary stability could be obtained, with the possibility of placing an immediately loaded provisional crown with an increased margin of safety.
28. A post-orthodontic stabilization phase to prevent relapse is not necessary. The periodontal fibres, being collagenic in nature (having none or very little elasticity), are subjected to substantial tensile stress (29). This stress, in part responsible for the deposition of bone (59) which typically accompanies the extrusion of the root, can, on other hand, also cause the partial re-intrusion of the tooth once the application of the orthodontic forces

are terminated. This does not occur with surgical extrusion because all of the periodontal fibres are completely lacerated and then successively become re-inserted in a new position without developing tension.

2.
3. For the patients:

1. Post surgical discomfort is minimal or absent
2. Absence of trouble due to the opening of spaces between the adjacent teeth (typical of deep surgical procedures of the periodontium) with phonetic and salivary control difficulties.
3. Reduced necessity for patient compliance (54): the patient has to simply not eat on the treated tooth and rinse with chlorhexidine for the recommended time.
4. Easy acceptance by the patient (58)
5. Cost reduction
6. Reducing the total treatment time

4.

Disvantages

Surgical extrusion exposes a reduced diameter of the root due to the root taper, making it difficult to manage the emergence profile and the inter-proximal space of the adjacent teeth during the restorative procedure (48, 50). In any case, these disadvantages are found as well in other surgical orthodontic procedures used for the recovery of tooth structure.

Complications

The complications associated with the surgical extrusion procedure (50) are:

6. Fracture of the residual root during the surgical extrusion manoeuvre.
7. Fracture of the alveolar bone. Normally fractures of small fragments heal spontaneously.
8. Radicular resorption.
9. Cervical resorption
10. Ankylosis

The three last complications (resorption and ankylosis) are well known with regard to re-implantation of teeth following traumatic avulsion or auto-transplantation, but their incidence is directly related to the amount of time the root is outside of the alveolus and the relative suffering and death of the periodontal cells (45). In the case of surgical extrusion this problem does not present itself as there is no period of time that the root is outside of the alveolus (35).
Again, there is unanimous agreement which retains that root splinting does not favour healing but that it may rather increase the risk of root resorption, if done in a rigid fashion for a too long period of time (61). On the contrary, functional stimulation seems to have an important role in guiding the correct orientation of the periodontal fibres in teeth that have been re- implanted following avulsion. Studies on monkeys have demonstrated a sharply higher incidence of root resorption in teeth that were re-implanted and splinted compared to those not splinted (61). It is therefore advisable, for this reason, to avoid rigid splinting for a period of more than 1-2 weeks.
In a study carried out on dogs, confronting teeth which had been extruded orthodontically with those extruded surgically, Kim in 2009 (62) found that in both groups there were areas of root resorption and ankylosis that were then repaired after a period of 90 - 120 days with new cementum and collagen fibres. This is in agreement with what Andreasen (60) found with teeth which were

immediately re-implanted after avulsion. In these we have the immediate formation of a coagulum to fill in the space of the periodontal ligament, then after three days this space is filled with connective tissue and after 1 week the junctional epithelium has recreated a seal at the root level. After 2 weeks, the disruption line at the level of the periodontal ligament is in the healing phase with collagen fibres that extend from the cementum surface to the alveolar bone. The resorption lacunae, observed as well by Kim, are of the non-progressive type and repaired with new cement produced from cells derived from the periodontal ligament adjacent to the lacunae. In the areas where the periodontal cells were traumatized, small zones of ankylosis are found, which successively heal by colonization from the adjacent area of the vital periodontal ligament. This transient replacement resorption is very different from progressive replacement resorption, typical of cases where the vitality of the entire periodontal ligament is lost and in time results in complete resorption of the root.
According to Kim et al (62), the small areas of superficial resorption that are present as histological pieces in surgical extrusion, could be due to:

3) the luxation manoeuvre which causes both tensile and compressive stress in the infra - osseous portion of the ligament in relation to the irregular section of the root.
4) the non standard positioning of the root in the alveolus at the end of extrusion with irregular formation and distribution of the periodontal ligament.

These histological studies confirm the good predictability for success of the surgical extrusion technique, with a low level of failure (52, 54, 57) and a good prognosis at a 10 year follow-up (63). Even the auto-transplantion technique has a good prognosis in both the follow-up (64) and from the literature review (58), however, it probably presents a higher risk of failure than surgical extrusion. This is most likely related to increased invasiveness, the time of the root outside of the alveolus and the very sensitive, high technique procedure. (Tab. 1)

Prognosis

Surgical extrusion has proven to be a procedure with a predictable outcome. The prognosis depends on (50, 52, 54, 57, 63):

- the amount of trauma that the periodontal cells are subjected to during the luxation manoeuvre.
- the type and period of splinting
- the condition and maintenance of the gingival tissues
- appropriate endodontic therapy

Kahnberg performed a 10 year follow up study (63), in which he reported only one extraction made 8 years after the procedure, due to cervical resorption. In other cases, modest apical resorption (about 0,5mm) was noted, however this did not compromise the function of the tooth. (Tab. 2)
The optimum predictability and prognosis is also confirmed by our experience with cases followed for more than 20 years (Fig. 6).

CONCLUSIONS

When the tooth margins subjected to caries or a fracture are positioned deep inside the gingival sulcus, it is common to recoup an adequate amount of tooth structure by extensive resective osseous surgery with or without orthodontic treatment. In more serious cases one may have to proceed with the extraction of the tooth and replacement with an implant.
Surgical extrusion allows one to save a tooth using a method that is simple, fast and with very little discomfort for the patient.
The only true complication of surgical extrusion is the fracture of the root during the luxation procedure, and therefore the patients must be well informed. Thus this technique is electively applied when there is severe coronal destruction, or when the patient refuses the usual surgical/ orthodontic technique to recoup tooth structure. Besides the technique can delay extraction of an hopelss tooth and the eventual insertion of an implant, and therefore is particularly indicated in young patients.
When paired with modern minimally invasive procedures, adhesive techniques and the latest generation of restorative materials, surgical extrusion is a conservative, simple and rapid technique in an optic of minimally invasive procedures.

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Captions

Fig. 1

A. Upper premolar with a deep fracture of the lingual wall.
B. Operation for clinical crown lengthening.

C. At the end of the operation the fracture margin is supra-gingival.

Fig. 2

A. Incongruous preparation on teeth 1.2 and 1.1 with encroachment of the biological width. Presence of infiltration at the level of the margins.
B. During orthodontic extrusion one notes the change in the alignment of the periodontal tissue.
C. Case completed with two all ceramic crowns and two ceramic veneers.

Fig. 3

A. Severe crown-root fracture of 1.1 and the crown of 1.2
B. The orthodontic extrusion phase of the two teeth. It is evident that the periodontal tissue is following the extrusion of teeth 1.2 and1.1.
C. After the surgical phase to reposition the periodontal tissues, one can note the reduced root diameter of 1.1 and the opening of the mesial interproximal space.
D. Case completed after cementation of the ceramic crowns on tooth 1.2 and 1.1 (Tech. Mr Giancarlo Barducci).

Fig. 4

A. After removal of the old metal-ceramic crown, tooth 1.3 was found to be totally destroyed by caries.
B. After carrying out surgical extrusion, the root was splinted to the adjacent teeth.
C. The reconstruction and preparation of the abutment.
D. The crown just after cementation (Tech. Mr. Massimiliano Pisa).
E. Radiograph taken 4 years after the extrusion.

Fig. 5

A. Total destruction of tooth 2.5 due to caries. It seems most likely that the tooth should be extracted.
B. Lateral view of the extruded tooth.
C. A lateral view of the reconstructed abutment.
D. After 9 weeks an overlay in composite is cemented (Tech. Mr. Massimiliano Pisa).

Fig. 6

A. Crown-root fracture of tooth 2.5 that extends to the bone crest.
B. Tooth 2.5 just after surgical extrusion and splinting to adjacent teeth.
C. Radiograph taken just after completing extrusion. Evident is the level of the moved tooth inside the alveolus.
D. The abutment of tooth 2.5 after removal of the splint.
E. The resin–gold crown cemented on tooth 2.5.
F. Bite-wing radiograph 20 years after the extrusion.
G. A clinical control 22 years following extrusion.

Fig. 7 Operation Sequence

A. Crown-root fracture
B. Surgical extrusion
C. Extrusion portion
D. Stabilization with flowable composite
E. Tissue healing
F. Final restoration

Fig. 8

A. Central incisors after surgical extrusion
B. The same tooth after the immediate placement of a thermo plastic Essix with a resin tooth fixed inside
C. A resin tooth fixed with a wire and orthodontic brackets to the adjacent teeth
D. Lingual view of the orthodontic provisional

Tab 1

Simplified comparative table of complications related to the different types of intervention of root recovery

Tab 2

Summary of adverse events following surgical extrusion: from Elkhadem 2013 modified by the authors

Case 1

1. Tooth 2.5 very compromised by caries.
2. The extrusion phase done with forceps.
3. At the occlusal level the amount extruded is evident.
4. Measurement of the vestibular wall done with a caliper.
5. The wall measures 2,1mm.
6. The build-up of the premolar.
7. The patient is dismissed with a light-cured provisional.
8. Stages of design and construction of CAD-CAM composite overlay (Courtesy of Mr. Massimiliano Pisa).
9. Adhesive cementation with composite.
10. The overlay just after cementation.
11. Lingual view of the tooth
12. Check up at 18 months
13. Radiographic control 18 month after extrusion

Case 2

1. A 52 year old patient.
2. Patient's smile.
3. The upper arch with a fixed metal-ceramic prosthesis from 1.2 to 2.2
4. A view of the lingual aspect of the fixed prosthesis.
5. Radiographs of tooth from 1.2 to 2.2
6. The appearance of the abutments after removal of the prosthesis.
7. Occlusal view of the abutments just after removal of the prosthesis.
8. Partial removal of the tissue damaged by caries on teeth 1.2 and 2.2.
9. The surgical extrusion phase of tooth 1.2.
10. The surgical extrusion phase of tooth 2.2.
11. The surgical extrusion of the lateral incisors just after completion with the sutures and a wooden wedge to maintain the correct position of tooth 1.2.
12. A view of the abutments after surgical extrusion of the lateral incisors.
13. Splinting of the lateral incisors with composite to the adjacent canines.
14. The old prosthesis after removal of the lingual portion.
15. Provisional cementation of the modified old prosthesis.
16. The patient as she was at dismissal following surgical extrusion.
17. An occlusal view after removal of the composite splint (ten days after surgical extrusion)

18. The radiograph done during endodontic re-treatment of the incisors (three weeks following surgical extrusion).
19. Final radiograph after completing endodontic re-treatment.
20. The condition of the periodontal tissue four weeks after surgical extrusion.
21. Rubber dam isolation of the abutments.
22. Occlusal view of the lateral incisors during the restorative phase.
23. Measurement of the abutment walls with a caliper.
24. Measurement of the height of the walls with a periodontal probe.
25. The restorations completed without the use of posts in any of the four abutments.
26. A view of the abutments after completion of the restoration.
27. The patient's smile with the resin provisional on the four incisors.
28. The patient's smile with the provisional.
29. The patient's smile with the mock up that extends to the second premolars. Note the improvement of the appearance of the labial corridors.
30. The mock up in resin that includes the canines and premolars.
31. Impression phase.
32. Occlusal view of the prepared teeth.
33. Laboratory phase (Courtesy of Mr Stefano Inglese)
34. Laboratory phase (Courtesy of Mr Stefano Inglese)
35. The etching phase of the enamel during the adhesive cementation of the additional – veneer on the first premolar.
36. Light-curing phase of the additional veneer on the first premolar.
37. The cementation phase of crowns, of the veneers on the canines and of the additional veneers on the first premolars just completed
38. Finishing phase with the removal of excess cement following rubber dam removal.
39. Frontal view just after finishing the cementation of the veneers and crowns.
40. The patient's smile after cementation of the veneers and crowns.
41. The radiograph of the central incisors following cementation of the crowns.
42. Frontal view of the smile at a check up.
43. Right lateral view of the smile at a check up.
44. Left lateral view of the smile at a check up.
45. Patient's smile at 2,5 years after extrusion.
46. Frontal view at 2,5 year after extrusion.