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CLINICAL RESEARCH

Surgical extrusion with an atraumatic extraction system: A clinical study

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ABSTRACT

Statement of problem. Clinical studies evaluating the feasibility of a novel technique for the surgical extrusion of nonrestorable teeth with subgingival caries are lacking.

Purpose. The purpose of this clinical study was to investigate the success rate and incidence of biological and technical complications after tooth extrusion with an atraumatic extraction system (AES).

Material and methods. Participants were recruited from 61 consecutive patients initially referred to a specialist oral surgery practice. Fifty-one participants who underwent surgical extrusion with an AES followed by endodontic treatment and coronal restoration could be re-evaluated clinically and radiographically.

Results. The mean observation period was 3.1 years (range: 0.8 to 6.5 years). The participants varied in age between 24.8 and 86.3 years. The amount of extrusion was between 2.5 and 5.0 mm (mean 3.2 mm). At recall, 92.2% (47 of 51) of the extruded teeth were considered successful. All extruded teeth were asymptomatic, without clinical signs of inflammation. Percussion appeared normal and did not differ from that of the adjacent teeth, indicating absence of ankylosis. Transient resorption with a slightly altered root contour was detected in 5 of the 51 teeth. Minor reduction of the bone level (less than 10%) was detected in 8 of the 51. In a further 2 teeth, bone loss amounted to 25% and 30%. Periapical periodontitis at recall was seen in 4 of the 51 teeth, and a preexisting periapical lesion healed in 10 of 13. Root perforation was identified in 3 of the 51, and a further 3 of 11 were not available for recall. Thus, the technical complication rate was 9.7% (6 of 62).

Conclusions. The AES may be successfully used for surgical extrusion to save apparently nonrestorable teeth, irrespective of patient age. (J Prosthet Dent 2018;120:879-85)

Teeth with deep subgingival fractures or carious lesions are usually deemed nonrestorable. When tooth preservation is nonetheless essential, all treatment options should be considered. Surgical crown lengthening can be performed to expose the root and allow restorative treatment. However, the reduction of alveolar bone may be associated with unfavorable gingival architecture and poor esthetic results in the anterior region.[1]

Orthodontic extrusion may be a suitable alternative for transposing the lesion to a more coronal position.[2,3] Limitations of this method include longer treatment duration and higher costs. Due to coronal movement of the gingiva and the supporting bone, periodontal surgery is often required to restore optimal gingival contour.[4]

Surgical extrusion, also referred to as intra-alveolar transplantation, was introduced as a more rapid alternative to orthodontic extrusion.[5-9] Because the tooth is first extracted, deep root injuries can be diagnosed more easily compared with orthodontic extrusion.[10] Prognosis after surgical extrusion has been favorable, but the evidence is limited.[11] A study evaluating periodontal healing after orthodontic versus surgical extrusion procedures in

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Clinical Implications

Teeth with deep subgingival fractures or carious lesions may be saved with surgical extrusion.

a dog model revealed favorable histological healing in both groups.[12] However, possible reduction of alveolar bone and root resorption remain a drawback of surgical extrusion.[13] To minimize these complications, minimally invasive extraction procedures that limit the trauma to the cementum, periodontal ligament, and bone may be advantageous.

An atraumatic extraction system (AES), termed Benex, was introduced primarily to reduce the trauma to the alveolar socket during tooth extraction to facilitate subsequent implant insertion.[14] Recently, a clinical report of surgical extrusion with an AES reported its minimally invasive nature with fewer complications compared with previous extrusion procedures.[15] Furthermore, an animal study revealed that teeth extruded by a specially designed extrusion instrument with a similar functional principle as that of an AES showed significantly less cementoblast loss than did teeth extracted using forceps.[16] Thus, the AES approach may reduce cemental damage and increase the likelihood of functional (periodontal) healing compared with conventional extraction methods.

The Idea, Development, Exploration, Assessment, Long-term (IDEAL) study collaboration provided a framework for the evaluation of surgical innovation, and the first cohort of patients treated with this technique, corresponding to IDEAL stage 2a, is described.[17] Therefore, the purpose of the present clinical study was to assess the success rate and the incidence of biological and technical complications after tooth extrusion with an AES.

MATERIAL AND METHODS

Study participants were recruited from a group of consecutive patients initially referred to a specialist oral surgery practice between January 2009 and July 2015 for possible extraction of their nonrestorable teeth. In 61 patients, 62 single rooted teeth were considered as potentially salvageable with surgical extrusion, despite subgingival fracture or caries. Ethical approval was obtained from the local ethics committee for the clinical and radiographic reevaluation after a follow-up period of a minimum of 9 months, and all participants provided written informed consent (EKNZ BASEC 2016-00374).

All surgical extrusions were performed by 1 experienced operator (B.S.) by using an AES apparatus (Benex; Helmut Zepf Medizintechnik GmbH) according to the manufacturer's instructions, and previously described in detail.[14] Briefly, a preoperative periapical radiograph was assessed to allow proper cavity access in all teeth. Root canals were enlarged with Gates-Glidden rotary instruments. A diamond rotary instrument was used to prepare an access cavity to enable the insertion of a matching self-tapping anchor screw (diameters 1.6 mm and 1.8 mm) in the coronal part of the root remnant. The AES device was assembled and placed on the adjacent teeth. A sectional impression tray with silicone impression material helped achieve proper placement and support. The drawstring was then attached to the anchor screw, and the tooth gradually extruded by increasing the traction force by turning the knob at the end of the extractor clockwise. If severe resistance was encountered, a constant force was applied for 30 to 40 seconds before any further increase in traction. After successful extraction, the teeth were replanted in a coronal position to permit subsequent crown restoration with an adequate ferrule. The root was immobilized by adhesive splinting to the adjacent teeth for up to 6 weeks. Postoperative periapical radiographs were made after splinting. In teeth without adequate endodontic obturation, endodontic treatment or re-treatment was initiated within the first 2 weeks. Endodontic obturation and restorative treatment with either a direct composite resin or crown was performed by the referring dentists. Figures 1 to 4 illustrate the treatment of a fractured lateral incisor.

Figure 1. Treatment of nonrestorable lateral incisor. Preoperative radiograph.

The follow-up examinations were performed after times ranging from 9 months to 6.5 years, with a median follow-up period of 3.1 years. The clinical examination included the presence or absence of clinical signs and symptoms such as pain, discomfort, sensitivity to

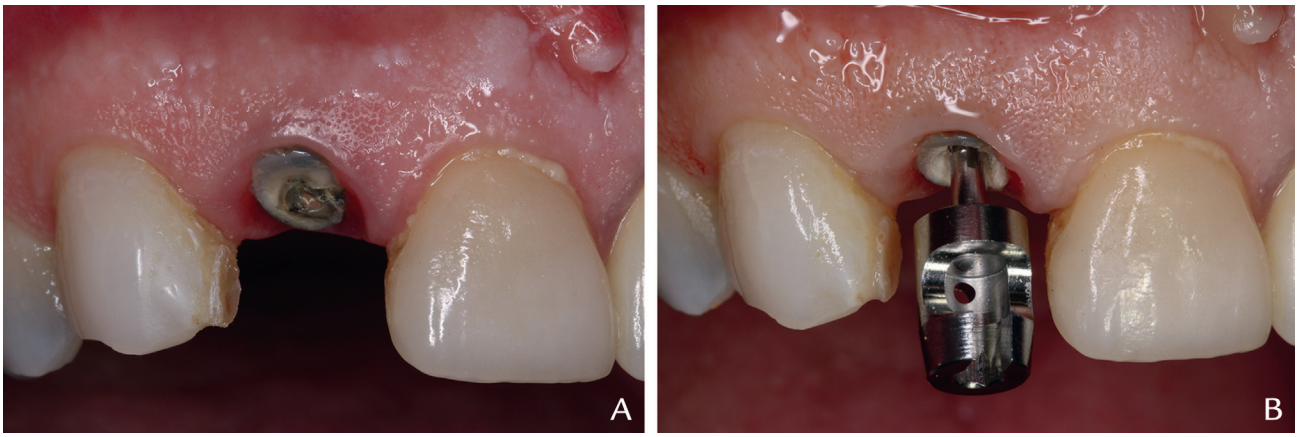

Figure 2. A, Clinical situation. B, Anchor screw (diameter 1.6 mm) of atraumatic extraction system inserted.

Figure 3. A, Extruded incisor. B, Restored tooth 1 year after surgical extrusion.

percussion, the presence of a sinus tract, assessment of probing pocket depths, and fractures. Special attention was paid to the percussion sound to facilitate the diagnosis of ankylosed teeth via the typical high, metallic tone. A periapical radiograph of each affected tooth was made and forwarded together with the preoperative and the postoperative radiograph to 2 calibrated, experienced endodontists (R.K., T.C.) for further analysis. The examiners were calibrated by evaluating 20 separate teeth with various types of root resorption.

The extent of extrusion was measured as the distance from the preoperative location of the root tip to its extruded position in the postoperative periapical radiograph by using tools in the proprietary software (Sidexis; Dentsply Sirona). To assess radiographic changes in the root, a root resorption index was applied.[18] Separate evaluations were made for the apical, middle, and coronal thirds of the root. Mesial and distal root contours were assessed separately and given a score from 0 to 2 (0: normal periodontal ligament without any visible resorption, 1: defects extending to less than half the distance between root surface and root canal wall, and 2: defects extending more than half the distance between root surface and root canal wall). The root resorption index was calculated as the sum of the scores of each of the 3 mesial and 3 distal sections. Resorptions were classified as infection-related (bowl-shaped radiolucencies), replacement (bone structure in the resorption area, loss of periodontal space), or transient resorption (altered root contour but visible periodontal space).

Marginal alveolar bone loss was evaluated radiographically. Corresponding radiographs of each tooth in the extruded position and at recall were superimposed as optimally as possible by using photoimaging software (Photoshop; Adobe Systems Inc). Reduced bone level at recall was quantified as a percentage in relation to a digital straightedge with 10 equal segments from the root tip to the original bone level.

The presence or absence of periapical radiolucencies was assessed on the preoperative and the recall radiographs. A periapical lesion was defined as a radiolucency connected to the apical portion of the root exceeding a size of at least twice the width of the periodontal ligament space.[19] Further, teeth were categorized according

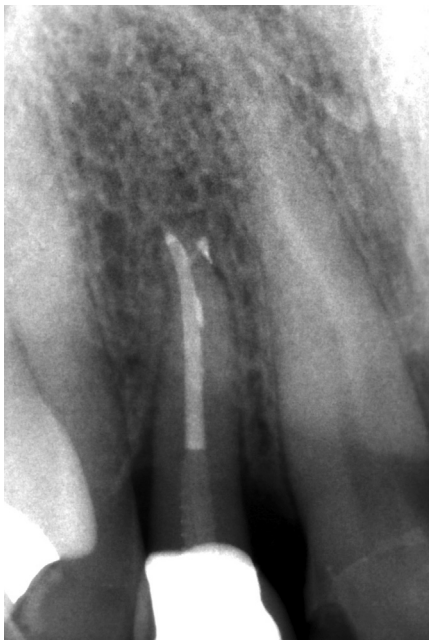

Figure 4. Periapical radiograph 1 year after surgical extrusion. Signs of root resorption or apical pathology absent; minimal distal marginal alveolar bone loss.

to the quality of the endodontic obturation as assessed from the radiograph and of the coronal restoration as previously described.[20] The presence and type of an endodontic post were ascertained from the patient notes.

The radiographs of each participant were independently evaluated twice at an interval of 3 months. In case of disagreement, the radiographs were discussed with a third examiner (G.K.) until consensus was reached. Clinical success was defined as a tooth that survived with no signs of infection-related resorption, replacement resorption, or periapical lesions at recall.

Summary statistics were calculated as appropriate. To estimate the proportions of the outcome variables, exact binomial 95% confidence intervals (CI) were calculated with statistical software (STATA v14; Stata Corp). Because the raters were fixed, the analysis of interrater reliability was based on a 2-way mixed model and calculated the intraclass correlation coefficient (ICC) with its referring CI (Table 1).

RESULTS

All 61 patients were invited for a follow-up examination. Eleven teeth could not be examined: 2 because of subsequent apical surgery, 2 because of extraction, and 2 because of patient death; 5 patients were unavailable. Thus, 51 participants with 51 treated teeth were recalled (82.3% recall). Of the 2 teeth extracted, 1 was extracted more than 5 years after extrusion because of a fractured coronal restoration. The other extracted tooth had been perforated during the extrusion attempt and was subsequently removed. Patient and tooth characteristics of the recalled teeth are given in Supplemental Table 1. The mean observation period was 3.1 (0.8 to 6.5) years. The participants varied in age between 24 and 86 years (mean 56.7 years). In total, 13 maxillary incisors, 14 maxillary canines, 16 maxillary premolars, 7 mandibular premolars, and 1 mandibular canine were re-evaluated. The amount of extrusion varied between 2.5 and 5.0 mm (mean ±SD, 3.2 ±0.7 mm). Good technical quality of both root canal treatment and coronal restoration was observed in 60.8% (31 of 51) of the teeth. Fiber posts were used in 74.5% (38 of 51).

Table 1. Results of interrater reliability

Radiographic Evaluation	Coefficient	ICC Value	Confidence Interval	Interpretation
Root resorption	Intraclass correlation	1	1	Very good
Perforation	Intraclass correlation	1	1	Very good
Loss of marginal alveolar bone	Intraclass correlation	0.951	0.924-0.969	Very good
Periapical lesion preoperative	Intraclass correlation	0.909	0.845-0.939	Very good
Periapical lesion at recall	Intraclass correlation	0.893	0.836-0.934	Very good
Technical quality of root canal filling	Intraclass correlation	0.956	0.933-0.973	Very good
Quality of permanent restoration	Intraclass correlation	0.908	0.858-0.943	Very good
Post	Intraclass correlation	1	1	Very good

Adapted from Saunders et al.[37]

Based on predefined criteria, 92.2% (47 of 51) of the extruded teeth met the success criteria at the recall examination. All extruded teeth were asymptomatic without clinical signs of inflammation. The percussion sound appeared normal and did not differ from that of the adjacent teeth, indicating absence of ankylosis. Analysis of the radiographs revealed periodontal healing with a visible periodontal ligament space around each root, without signs of infection-related or replacement resorption. Transient resorption with a slightly altered root contour and a resorption score of 1 was detected in 5 of the 51 teeth (10%, 95% CI: 3.3%, 21%).

Periapical lesions were seen in 4 teeth at recall. A preexisting periapical lesion healed in 10 of 13 teeth. All periapical lesions and transient resorptions occurred in different teeth. Minor reduction of the bone level (less than 10% of the supporting alveolar bone) was detected in 8 of the 51 teeth. In a further 2 teeth, bone loss amounted to 25% and 30%.

Root perforation was identified radiographically as a technical complication during preparation for the AES anchor screw in 3 of the 51 recalled teeth. This event did not seem to compromise periodontal healing in these teeth. Additionally, root perforation was detected from

the immediate postoperative radiographs in a further 3 of the 11 teeth not available for recall. Thus, the overall technical complication rate was estimated at 9.7% (95% CI: 3.6%, 20%). In 3 of these 6 teeth, perforation occurred in roots with calcified endodontic canals.

In this study, the success rate was 92.2% (47 of 51) for the recalled teeth surgically extruded with the AES.

DISCUSSION

The present study showed a favorable outcome after surgical extrusion of nonrestorable teeth with a novel vertical extrusion system. In the patients treated, 82.3% of teeth deemed nonrestorable at referral could be reevaluated and were in function without any clinical or radiographic complications. In particular, none of the treated teeth showed infection-related or replacement resorption, whereas periodontal healing with transient resorption was detected in 9.8% of recalled teeth. Some marginal bone loss occurred in 19.6%, and technical complications at the time of extrusion occurred in 9.7%.

The primary focus of this clinical study was to detect root resorption as a relevant biological complication after surgical extrusion. To avoid errors resulting from late healing complications, a sufficiently long observation period is required. While infection-related root resorption is usually detected radiographically within the first weeks after replantation,[21] radiologic evidence of replacement resorption usually requires 1 year.[22] However, clinical signs of ankylosis, such as lack of normal tooth mobility and a high metallic percussion sound, usually precede the radiographic diagnosis and are detected 4 to 8 weeks after replantation.[22] As 50 of 51 participants in the present study were followed up for more than 1 year both clinically and radiographically, we assume that all healing complications could be detected. However, in rare situations, late resorptions may take up to 3 years to be detectable radiographically.[23] Therefore, the possibility that some of the teeth with follow-up times of less than 3 years may develop late resorptions cannot be ruled out.

In the present study, radiologic assessment of root resorption and periapical health was performed solely from periapical radiographs. The accuracy of digital periapical radiographs in detecting root resorptions is known to be inferior compared with that of cone beam computed tomography (CBCT). Numerous clinical and experimental studies highlighted the high sensitivity and specificity of CBCT in diagnosing early stages of root resorptions, especially infection-related resorption.[24-28] Likewise, the diagnosis of apical periodontitis based on periapical radiographs is clinically limited compared with CBCT.[29,30] Despite these limitations, the use of intraoral digital periapical radiographs was considered to be sufficient for this evaluation, as CBCT imaging would not have been justifiable due to the higher radiation dose. The occurrence of infection-related resorption was assumed to be low because of the timely endodontic treatment in all extruded teeth. For replacement resorption, the additional diagnostic value of CBCT compared with periapical radiographs is questionable, as recently shown.[28]

With a mean age of 57 years, the patients treated in this study were considerably older than those in comparable studies in which the mean age ranged between 15 and 31 years.[7,9,10,31] Moreover, in the present investigation, only 4 participants were younger than 30 years; almost 60% of the participants were older than 55 years. Age-associated changes of the periodontal ligament space leading to apposition of cementum and increased fibrosis and decreased cellularity of the periodontal ligament tissue have been reported.[32,33] Thus, different tissue reactions after tooth extraction and replantation might have occurred. Nevertheless, the favorable outcome in this study, with periodontal healing in every treated tooth, demonstrates that surgical extrusion can be successfully performed even beyond the fifth decade of life.

A recent systematic review focusing on the adverse events of surgical extrusion based on 11 case reports and 8 case series involving 226 mostly young patients with 243 teeth revealed that nonprogressive root resorption was the most common finding, with an event rate of 30%, followed by tooth loss (5%), slight mobility (4.6%), marginal bone loss (3.7%), and progressive root resorption (3.3%).[13] The very low occurrence of biological complications in the present study may be attributed to the axial extrusion technique, which avoids compression of the periodontal tissues. An animal study revealed that locations that are more compressed during conventional tooth extraction by using forceps show more cementoblast loss and are thus more likely to develop root resorption.[16] Because most extruded teeth in the present investigation were maxillary canines or premolars and because these teeth usually do not depict circular root cross sections, a higher risk of resorption could have been expected if the root had been compressed against the alveolar socket when applying rotation movements.

The 20% rate of marginal bone loss detected in the present study seems rather high. However, for most teeth, bone loss was minor and did not exceed 10% of the supporting bone. Posterior teeth seem to be more affected by a reduction in alveolar bone after surgical extrusion than are anterior teeth. Posterior teeth characterized by more distinctive grooves on the root surface and located in a wide alveolar crest might be more susceptible to changes of interdental proximity. However, knowledge of differences in the outcome of surgically extruded premolars to anterior teeth is low. Previous studies have mainly focused on the extrusion of anterior teeth.[7,9,10]

The applicability of the AES for minimally invasive tooth extraction was documented in a proof of principle clinical study. However, extraction failures, resulting from insufficient retention or misplacement of the screw, root fractures, or unfavorable root morphology occurred in 11% of single-rooted teeth.[14] In the present study, root extrusion was successful, without any occurrence of root fracture or retention loss. Nonetheless, root perforation with the AES screw occurred in 6 teeth, especially in calcified root canals. This technical complication may be preventable if the root canal is enlarged to obtain a drill path for proper alignment of the AES screw. Half of the perforations occurred in roots with fully calcified root canals (3 teeth). Guided endodontic procedures could be used to locate the root canal and prevent perforation in these situations.[34] None of the 3 teeth with root perforation available at recall showed healing complications in terms of progressive resorption or apical or lateral periodontitis. The results suggest that subcrestal perforations do not necessarily lead to tooth loss. High survival rates after perforation repair with mineral trioxide aggregate have been recently reported.[35] Furthermore, in situations of surgical extrusion the repair of a perforation can, under ideal conditions, be performed extraorally before replantation of the root.

The results of this study are encouraging, even after follow-up periods of up to 6 years. However, longer observation periods are needed to evaluate whether long-term tooth preservation is achievable and whether the outcomes for this approach compare with alternatives such as surgical crown lengthening. For example, the AES screw needed for retention in the post space and the axial force applied during extrusion may induce microcracks into the dentin, possibly leading to vertical root fracture later. In fact, a high failure rate of teeth restored with metal screw posts was documented.[36] Similarly, the loss of dentin itself as a significant side effect of insertion of the AES screw may affect the outcome.

CONCLUSIONS

Based on the findings of this clinical study, the following conclusions were drawn:

1. The AES may be successfully used for surgical extrusion to save nonrestorable teeth.
2. These results encourage further prospective research into the long-term outcomes of this technique.

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Noteworthy Abstracts of the Current Literature

Stresses in implant-supported fixed complete dentures with different screw-tightening sequences and torque application modes

Barcellos LH, Palmeiro ML, Naconecy MM, Geremia T, Cervieri A, Shinkai RS
Int J Prosthodont 2018;31:492-3

Purpose. To compare the effects of different screw-tightening sequences and torque applications on stresses in implant-supportedfixed complete dentures supported by five abutments.

Material and methods. Strain gauges fixed to the abutments were used to test the sequences 2-4-3-1-5; 1-2-3-4-5; 3-2-4-1-5; and 2-5-4-1-3 with direct 10-Ncm torque or progressive torque (5+10 Ncm). Data were analyzed using analysis of variance and standardized effect size.

Results. No effects of tightening sequence or torque application were found except for the sequence 3-2-4-1-5 and some small to moderate effect sizes.

Conclusions. Screw-tightening sequences and torque application modes have only a marginal effect on residual stresses.

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