Effectiveness of a Piezoelectric-Assisted Distraction Osteogenesis Procedure for the Treatment of Ankylosed Permanent Front Teeth

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Abstract: A common complication of tooth replantation after traumatic avulsion is tooth ankylosis causing dental malpositioning, partial loss of function, tipping of adjacent teeth and worsening of aesthetics. The aim of this study is to evaluate the effects of a repositioning procedure of such ankylosed permanent front teeth by a distraction osteogenesis procedure. Five patients (mean age 13.4 years), with an ankylosed permanent front tooth in the anterior area, were enrolled in the present study. After the pre-operatory orthodontic preparation, each selected site was treated with single-tooth dento-alveolar block osteotomy surgery performed with a piezoelectric surgery device with ultrasonic cuts on the buccal side. Subsequently, a custom distraction device, made by a resin splint and a sector expansion screw, was set in such a way it delivered a force with direction and sense towards the planned position of the tooth as well as the osteotomy's incision. After a latency period of 14 days, the distraction of the dento-alveolar block was started with a rate of distraction of 0.8 mm per day. The average shift obtained by the ankylosed teeth was 7.8 ± 0.75 mm ($\pm$SD), and the ankylosed tooth was regularly positioned into the occlusion in 20.4 ± 1.85 days ($\pm$SD), with a slight relapse ($\pm$0.5 mm) observed after 1 year. This study indicates that a therapeutic approach combining piezoelectric surgery and orthodontic therapy may be useful for the treatment of ankylosed permanent teeth in the frontal area with a long-term follow-up over 5 years.

Key Words: Distraction osteogenesis, long-term follow-up, orthodontics, piezoelectric surgery, tooth ankylosis

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Tooth loss following a maxillo-facial trauma is reported in 0.5% to 3% of cases involving the anterior dentition.[1] Tooth replantation may be successful in the short term, but long-term survival of the tooth is frequently questionable, leading even to tooth loss or extraction at a later stage.[1] If tooth is not replanted immediately or if it is not stored in a suitable environment before replantation, it's more likely to develop root resorption compared with tooth replanted after few minutes or stored under favourable conditions.[2] Severe injuries to periodontal ligament remnants may lead also to ankylosis phenomenon causing the fusion between the mineralized root surface and the alveolar bone.[3] If ankylosis occurs in a growing child, tooth remains in a state of static retention whereas, in the adjacent areas, tooth eruption and alveolar growth continue. The orthodontic tooth movement may determine incomplete alveolar process development, replanted tooth infraocclusion, occlusal disharmony, tipping of adjacent teeth, supra-eruption of opposing teeth, delayed tooth movements, and, if affecting permanent maxillary incisors, an anesthetic smile.[4] In such a case absence of the physiological response to orthodontic forces occurs and any following treatment, that initially requires the extraction of ankylosed tooth, is generally aggravated by the complexity of extraction procedures leading often to severe deficiencies of alveolar hard and soft tissues.[5]

When performing a treatment aiming to maintain and reposition an ankylosed tooth, the role of surgery becomes fundamental in conjunction with orthodontic therapy. Different surgical techniques have been described for the facilitation of orthodontic tooth movements such as corticotomy[6] and distraction osteogenesis.[7] According to Long et al[8] both surgical procedures are effective and safe to accelerate orthodontic movement of teeth with a healthy periodontal ligament. Regarding ankylosed permanent front teeth, several case reports have shown good results with different techniques for tooth repositioning.[9,10] A reported procedure is distraction osteogenesis (DO) that consists in carrying out subperiosteal osteotomies leading to a bone block containing the ankylosed tooth. This is followed by a controlled slight displacement of surgically created bone segment through orthodontic incremental tractions that let bone and soft tissue to expand due to mechanical tissue stretching at the osteotomy site.[7,11]

The aim of this study is to describe a long-term follow-up of a case series of ankylosed permanent front teeth repositioned by orthodontic displacement of a dento-alveolar block according to distraction osteogenesis procedure.

METHODS

Five patients (2 males and 3 females; aged 12–15 years; mean age: 13.4 years), in permanent dentition who needed orthodontic treatment with fixed appliances, with a chief complaint of irregular teeth eruptions in the anterior area and an ankylosed permanent front tooth, were enrolled in the present study. For each patient, informed written consent was collected about the possible risks of the study. The institutional ethical committees of the University of Naples "Federico II" and of the University of Messina approved the study protocol (#18/04 and #22/05).

The inclusion criteria were as follows:

(1) irregular teeth eruptions in the anterior area scheduled for orthodontic treatment,
(2) ankylosis of a permanent front tooth (not responding to orthodontic forces),
(3) absence of active periodontal disease with good plaque control,
(4) no history of systemic diseases that would contraindicate oral surgical treatment.[12]

Before the surgical procedure, each patient was given supplemental oral hygiene instructions and underwent full-mouth

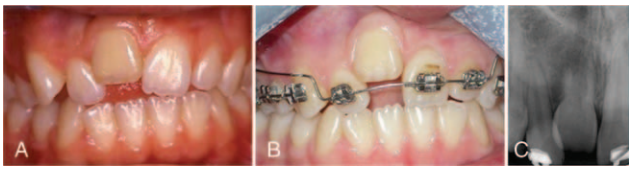

FIGURE 1. A, B, and C, Initial case and orthodontic treatment.

supragingival scaling with ultrasonic devices and/or hand instrumentation. Before the surgery, the space for the repositioning of the ankylosed tooth was orthodontically created.

After the pre-operatory orthodontic preparation, the site was ready for the single-tooth dento-alveolar block osteotomy surgery (Fig. 1A–C).[13] The extension of the mucoperiosteal flap included the ankylosed tooth and at least the mesial and distal teeth from the distal interdental papillae (Fig. 2A). The osteotomy was performed with a piezoelectric surgery device using thin inserts OT7 or OT2 piezoelectric surgery tips (Mectron s.p.a., Carasco, Genova, Italy).[14] Two vertical osteotomies were made right in the middle of the inter-radicular space, mesially and distally the ankylosed tooth, and a horizontal osteotomy was made to connect the other 2 (Fig. 2B). All the osteotomy cuts reached the palatal mucosa, and the osseous box containing the ankylosed tooth had to be displaceable towards the desired position. (Fig. 2C). Ultrasonic cuts were generated on the buccal side.

The flap then was replaced in his original position and sutured with nonabsorbable silk surgical suture 4–0 (Fig. 2D and E).

In all patients, amoxicillin was prescribed (1 g 2 times a day for 3 days), and a 0.12% chlorhexidine solution (rinsing twice a day, starting 24 hours after surgery for 7 days).

The custom distraction device was made for the patients, using a resin splint and a sector expansion screw. The splint was made of:

1) the passive part, that was cemented to the occlusal surface of all the upper arch teeth except the ankylosed one;
2) the active part, that was the movable part of the screw bonded to the widest possible surface of the ankylosed tooth's crown with orthodontic bonding and composite resin (Fig. 3A and B). The screw was set in such a way it delivered a force with direction and sense towards the planned position of the tooth as well as the osteotomy's incision (Fig. 3B).

After 10 days from the surgical procedure, the distraction device was bonded to the maxillary teeth. After a following latency period of 4 days, the distraction of the dento-alveolar block was started. Each activation equivalent to 0.4 mm, was made twice a day (Fig. 3A) with a rate of distraction of 0.8 mm per day. The position of the ankylosed tooth was overcorrected by 1 mm. The changes in the movement of the ankylosed treated tooth over time were recorded.

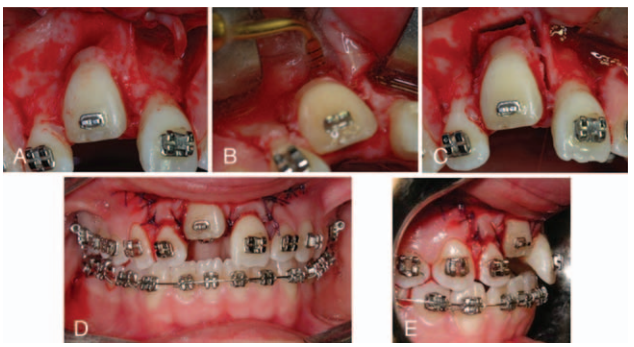

FIGURE 2. A, B, and C, Osteotomy performed with a piezoelectric device; D and E, immediate post-surgical stage.

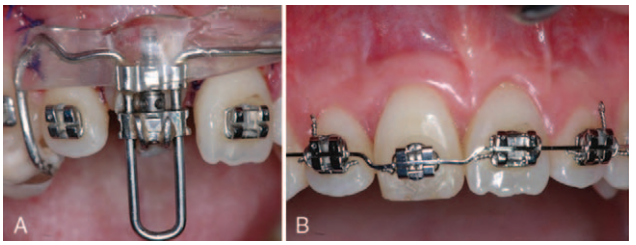

FIGURE 3. A, Application of the osteodistraction device; B, Active orthodontic treatment and stabilization of the ankylosed tooth.

After active orthodontic treatment, the stabilization of the dental arch was obtained with an SS .019 x .025 arch wire (Fig. 3B).

RESULTS

Table 1 shows the patients data. A better smile aesthetic and a normo-occlusion have been reached in the anterior region due to the regularisation of overbite and overjet values of the ankylosed tooth in all patients. In the analyzed sample, the average shift obtained from the ankylosed teeth was 7.8 ± 0.75 mm ($\pm$SD), and the ankylosed tooth was regularly positioned into the occlusion in 20.4 ± 1.85 days ($\pm$SD). When the ankylosed tooth reached the occlusal plane, an arch wire retainer, including the ankylosed teeth, was inserted for a period of 6 months to monitor the evolution. A slight relapse (± 0.5 mm) observed after 1 year and then stable in the long term.

At the 24-month post-treatment follow-up, the maxillary anterior gingival margins were improved, and alignment and leveling were completed in both arches (Fig. 4A and B). A normal overjet and overbite improved the midline coincidence, and Class I molar and canine relationships were obtained. The post-treatment radiograph after more than 5 years of follow-up showed that the root of the ankylosed tooth presented the same stable root reabsorption of the final active treatment (Fig. 5A and B).

Even with different events occurred during the treatment (such as little relapse or aesthetic requests), the clinical procedure allowed the patient to maintain function and a good aesthetic without any prosthetic solution. Advantage of this procedure is the recreation of healthy hard and soft tissues, that could in anytime be used to place an implant to improve further the smile aesthetic.

DISCUSSION

After traumatic dental avulsion tooth ankylosis, due to severe injuries of the periodontal ligament, is a common complication of tooth replantation. Ankylosis of permanent teeth in the frontal area may cause dental malpositioning, partial loss of function,

TABLE 1. Clinical Results

Patient	Age	Sex	Ankylotic Tooth	Shift Obtained (mm)	Expansion Duration (days)
E.R.	12	F	1.1	8	20
G.A.	13	M	1.1	8	22
A.S.	13	M	1.2	7	19
C.M.	15	F	2.1	9	23
G.T.	14	F	2.2	7	18
Average Value	13.4	/	/	7.8 ± 0.75	20.4 ± 1.85

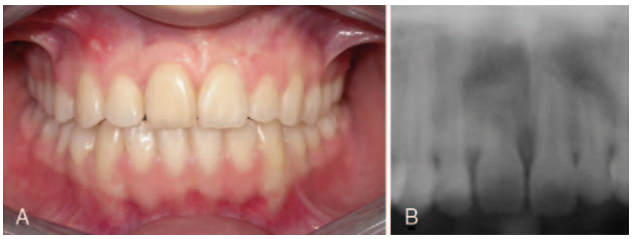

FIGURE 4. A and B, 2-year follow-up retention of ankylosed treated teeth in the frontal area.

FIGURE 5. A and B, 7-year follow-up retention of ankylosed treated teeth in the frontal area.

tipping of adjacent teeth and worsening of aesthetics. For a functional and aesthetic rehabilitation of such condition, sometimes vertical bone augmentation by tissue regeneration or bone grafting is necessary. However, techniques that require bone augmentation in some cases have shown conflicting results, particularly in cases of vertical bone augmentation.[15,16] Maintaining the tooth on the arch and moving it to the occlusal plane would be a better treatment option.

For the relocation of ankylosed teeth, a technique proposed in the literature is the segmental osteotomy.[17] The immediate mobilization and repositioning of the alveolar segment, associated or not with xenogenic bone grafts,[18] seems to be a surgical repositioning technique with satisfactory results.[19] For this procedure, maintenance of the vascularization is an important factor for the long-term result of the soft and hard tissues of the ankylosed tooth.[19,20] To enable a gradual and slower soft tissue stretching, an osteotomy associated with a distraction device has been proposed to treat ankylosed teeth.[21] Although adequate results have been reported, these techniques use a specific device that is sometimes complex and constraining. Furthermore, distractors have a unidirectional impact with heavy strengths (distraction rate of 0.5 to 1 mm/day). These techniques poorly predict movement in the sagittal direction and can lead to incorrect distraction vectors.[22]

The piezoelectric surgery is a technique that provides precise bone cutting and increased tactile control since the application of excessive force is not needed as with conventional drills.[23] The vibrating tip also drives the irrigation solution through a cavitation phenomenon which allows for better visibility and a clean operating field.[24] Therefore, the surgeon can safely and precisely carry out the bone surgery, with minimal chances of instrument slippage which can damage the adjacent tissues. In contrast to macrovibrations produced by conventional drills, piezoelectric surgery acts on the principle of microvibrations thus minimizing the patient's psychological stress and fear.[21,25]

Wilcko et al[26] proposed that it is possible to maintain and even thicken the layer of pre-treatment bone over the prominences of the roots without increasing the risk of apical root resorption. Furthermore, corticotomy by piezoelectric bone surgery seems to be an effective treatment that allows to decrease the time required for the orthodontic movement as well as reducing the root resorption rate.[27]

The repositioning procedure of ankylosed permanent front teeth by a distraction osteogenesis. approach combining piezoelectric surgery and orthodontic therapy may be useful for the treatment of post-traumatic replanted teeth showing an ankylotic complication.

The single tooth dento-alveolar osteotomy technique proposed in the present study resulted in clinical outcomes that were similar to those of the classic decortication approach. In contrast to the findings of Yaffe et al,[28] who reported slight interdental bone loss, reduced attached gingiva, and periodontal defects, we observed no significant negative effects on the periodontal tissues after osteotomy performed by piezoelectric surgery. In fact, this kind of bone movement allowed for the adaptation of the soft gingival tissues in the area of the ankylosed tooth.[29–31]

Moreover, this approach presented the additional advantages of being minimally invasive, precise, and less traumatic for the patient.

This study indicated the effectiveness of the combined surgical-orthodontic approach using osteotomy performed with the piezoelectric surgery and segmental alveolar bone distraction for the treatment of ankylosed tooth in the frontal area. The advantages of this approach were a 3-dimensional fine movement of the ankylosed tooth and prevention of alveolar bone loss and recession of gingival margins in a long-term follow-up. Over 5-years follow-up retention of ankylosed treated teeth in the frontal area was achieved without any negative effect on the aesthetic appearance in terms of infra-occlusion and gingival irregularity due to surrounding alveolar growth.

The results of the present study are promising and demand further studies with a larger sample to better understand the role and benefits of the reported combined surgical-orthodontic procedure in the management of ankylosed permanent front teeth.

REFERENCES

1. Jepsen K, Schneider E, Dommisch H, et al. Management of a central incisor with horizontal root fracture for esthetic and functional rehabilitation. *Int J Periodontics Restorative Dent* 2016;36:65–73
2. Bertl MH, Frey C, Bertl K, et al. Impacted and transmigrated mandibular canines: an analysis of 3D radiographic imaging data. *Clin Oral Investig* 2018;22:2389–2399
3. Campbell KM, Casas MJ, Kenny DJ. Ankylosis of traumatized permanent incisors: pathogenesis and current approaches to diagnosis and management. *J Can Dent Assoc* 2005;71:763–768
4. Isola G, Matarese G, Cordasco G, et al. Mechanobiology of the tooth movement during the orthodontic treatment: a literature review. *Minerva Stomatol* 2016;65:299–327
5. Winter GB, Gelbier MJ, Goodman JR. Severe infra-occlusion and failed eruption of deciduous molars associated with eruptive and developmental disturbances in the permanent dentition: a report of 28 selected cases. *Br J Orthod* 1997;24:149–157
6. Troiano G, Inghingolo A, Serpico R, et al. Rate of relapse after enucleation of solid/multicystic ameloblastoma followed by piezoelectric or conventional peripheral ostectomy. *J Craniofac Surg* 2018;29:e291–e293
7. Antonarakis GS, Joss CU, Triaca A, et al. Gingival recessions of lower incisors after proclination by orthodontics alone or in combination with anterior mandibular alveolar process distraction osteogenesis. *Clin Oral Investig* 2017;21:2569–2579
8. Long H, Pyakurel U, Wang Y, et al. Interventions for accelerating orthodontic tooth movement: a systematic review. *Angle Orthod* 2013;83:164–171
9. You TM, Kang JH, Kim KD, et al. Single-tooth osteotomy using piezoelectric devices to treat an ankylosed maxillary molar. *Int J Periodontics Restorative Dent* 2016;36:e1–e8
10. Verardi S, Pastagia J. Patient-based comparison of traditional instruments and piezoelectric bone surgery in osseous resective surgery. *Int J Periodontics Restorative Dent* 2017;37:433–440

11. Senişik NE, Koçer G, Kaya BÜ. Ankylosed maxillary incisor with severe root resorption treated with a single-tooth dento-osseous osteotomy, vertical alveolar distraction osteogenesis, and mini-implant anchorage. *Am J Orthod Dentofacial Orthop* 2014;146:371–384
12. Isola G, Matarese G, Cordasco G, et al. Anticoagulant therapy in patients undergoing dental interventions: a critical review of the literature and current perspectives. *Minerva Stomatol* 2015;64:21–46
13. Hoogeveen EJ, Jansma J, Ren Y. Surgically facilitated orthodontic treatment: a systematic review. *Am J Orthod Dentofacial Orthop* 2014;145:51–64
14. Vercellotti T. Technological characteristics and clinical indications of piezoelectric bone surgery. *Minerva Stomatol* 2004;53:207–214
15. Natto ZS, Yaghmoor W, Bannuru RR, et al. Identification and efficacy ranking of allograft and xenograft for extraction and ridge preservation procedures. *Int J Periodontics Restorative Dent* 2017;37:e253–e260
16. Martuscelli R, Toti P, Sbordone L, et al. Five-year outcome of bone remodelling around implants in the maxillary sinus: assessment of differences between implants placed in autogenous inlay bone blocks and in ungrafted maxilla. *Int J Oral Maxillofac Surg* 2014;43:1117–1126
17. de Souza RF, Travess H, Newton T, et al. Interventions for treating traumatised ankylosed permanent front teeth. *Cochrane Database Syst Rev* 2015:CD007820
18. Ramaglia L, Saviano R, Matarese G, et al. Histological evaluation of soft and hard tissue healing following alveolar ridge preservation with deproteinized bovine bone mineral covered with xenogenic collagen matrix. *Int J Period Restorative Dent* 2018;38:737–745
19. You KH, Min YS, Baik HS. Treatment of ankylosed maxillary central incisors by segmental osteotomy with autogenous bone graft. *Am J Orthod Dentofacial Orthop* 2012;141:495–503
20. Lorenz J, Kubesch A, Al-Maawi S, et al. Allogeneic bone block for challenging augmentation-a clinical, histological, and histomorphometrical investigation of tissue reaction and new bone formation. *Clin Oral Investig* 2018;22:3159–3169
21. Tosun E, Bilgiç M, Yildirim B, et al. Effects of piezoelectric surgery on bone regeneration following distraction osteogenesis of mandible. *J Craniofac Surg* 2017;28:74–78
22. Mazzonetto R, Allais M, Maurette PE, et al. A retrospective study of the potential complications during alveolar distraction osteogenesis in 55 patients. *Int J Oral Maxillofac Surg* 2007;36:6–10
23. Hernando J, Aguilar-Salvatierra A, Leizaola-Cardesa IO, et al. Piezosurgery for treatment of large recurrent mandibular osteoma. *J Craniofac Surg* 2018;29:e219–e221
24. Stacchi C, Lombardi T, Cusimano P, et al. Bone scrapers versus piezoelectric surgery in the lateral antrostomy for sinus floor elevation. *J Craniofac Surg* 2017;28:1191–1196
25. Vercellotti T, De Paoli S, Nevins M. The piezoelectric bony window osteotomy and sinus membrane elevation: introduction of a new technique for simplification of the sinus augmentation procedure. *Int J Periodontics Restorative Dent* 2001;21:561–567
26. Wilcko WM, Wilcko MT, Bouquot JE, et al. Rapid orthodontics with alveolar reshaping: two case reports of decrowding. *Int J Periodontics Restorative Dent* 2001;21:9–19
27. Viwattanatipa N, Charnchairerk S. The effectiveness of corticotomy and piezocision on canine retraction: A systematic review. *Korean J Orthod* 2018;48:200–211
28. Yaffe A, Fine N, Binderman I. Regional accelerated phenomenon in the mandible following mucoperiosteal flap surgery. *J Periodontol* 1994;65:79–83
29. Yang S, Jung BY, Pang NS. Outcomes of autotransplanted teeth and prognostic factors: a 10-year retrospective study. *Clin Oral Investig* 2019;23:87–98
30. Isola G, Matarese G, Cervino G, et al. Clinical efficacy and patient perceptions of pyogenic granuloma excision using diode laser versus conventional surgical techniques. *J Craniofac Surg* 2018;29:2160–2163
31. Pascual A, Barallat L, Santos A, et al. Comparison of periodontal biotypes between maxillary and mandibular anterior teeth: a clinical and radiographic study. *Int J Periodontics Restorative Dent* 2017;37:533–539

Minimally-Invasive Endoscopic-Assisted Sinus Augmentation

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Objectives: The purpose of this article is to evaluate endoscopic-assisted technique by lateral approach for sinus floor augmentation, to reduce the incidence of Schneiderian membrane perforation, and to guarantee a sufficient apposition of new bone even in the posterior maxillary sinus.

Methods: From January 2017 to December 2017, 10 patients affected by severe maxillary atrophy underwent endoscopic-assisted sinus augmentation using a lateral approach.

Results: In only 1 patient, a little perforation of sinus membrane was observed intraoperatively and it was repaired. No abnormal postoperative bleeding was observed. None of the patients experienced oro-antral fistula, infection, or V2 dysesthesia. The authors did not find radiologic evidences of biomaterial displaced on the maxillary sinus or postoperative sinusitis.

Conclusions: The authors evaluated endoscopic-assisted maxillary sinus augmentation technique using a lateral approach that allows a direct and clear view of the surgical field. This technique, as the preliminary results demonstrate, is safe and helpful, especially in avoiding membrane perforation and in xenograft optimal distribution. It could be very useful in retreatment patients.

Key Words: Endoscopic assisted, implant surgery, maxillary sinus augmentation, minimally-invasive sinus lift

Maxillary sinus floor augmentation is a surgical procedure that allows the rehabilitation of atrophic edentulous posterior maxilla and is crucial to dental implant procedure. New homologous or heterologous bone graft could be used to increase maxillary sinus floor bone height.[1] Tatum[2] and Boyne and James[3] 1st described the lateral approach, which consisted in drilling a window in the lateral sinus wall to access to the Schneiderian membrane. In the following years, a lot of modifications of this technique have been published, and when the increase of vertical bone is <9 mm, a transcrestal technique could be indicated.[4–6] Some complications have been described: sinusitis, displacement of heterologous bone graft into the maxillary sinus, abscesses, and Schneiderian membrane perforation.[7] To avoid these complications, some works about endoscopic-assisted transcrestal sinus lift have been reported.[8–10] In the present work, we propose an endoscopic-assisted sinus floor augmentation associated with lateral maxillary wall approach to

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