INTRODUCTION

Continuous alveolar ridge resorption following tooth extraction often produces unfavorable conditions of soft and hard tissues for implant surgery. An atrophic ridge compromises the functionality and aesthetics of implant prostheses, especially in the esthetic zone at the anterior maxilla. Periodontists have persistently sought ways to improve the implant site. Guided bone regeneration (GBR) and muco-gingival surgery are commonly used methods for preparing the implant site. Immediate implantation at the anterior maxilla maintains esthetics and biological function; however, when the condition of the soft and hard tissue at the extraction site is less than ideal, it is not an option. In 1993, Salama introduced a non-surgical method, slow orthodontic extrusion (SOE), to improve the 3D topography of both the soft and hard tissues at the implant site prior to extraction. SOE is an option for eliminating alveolar ridge defects when there is a single hopeless tooth in the esthetic zone at the anterior maxilla and implant reconstruction is planned for the missing tooth space.
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The theoretical basis for SOE as a clinical technique is that when the periodontium is healthy, optimal tension force will cause new bone to form at the tension side of the periodontal ligament (PDL). Consequently, a series of studies have been done to clinically test the response of hard and soft tissues to SOE, as well as its histological effects on bone and gingiva.

More than twenty years have passed since SOE was first introduced, yet we have only case reports/case series or retrospective reviews of this procedure in clinical practice. A clear comparison between SOE and GBR surgery cannot be made due to the lack of evidence about SOE treatment efficacy. This paper investigates the requirements for immediate implantation and uses a clinical case to analyze new bone generated by SOE at the implant site. We discuss the benefits of this technique and whether orthodontists can use SOE to achieve the specific conditions required for immediate implantation in the esthetic zone at the anterior maxilla. In addition, we also review the literature and evaluate the quality of available evidence on SOE outcomes found in case reports on PubMed.

CASE REPORT

A 24-year-old female patient had a hopeless #21 tooth due to dental caries at the distal side of the tooth (Figure 1).

Clinical findings

Distal out-rotation of 21 was observed, causing insufficient mesio-distal dimensions for prosthetic reconstruction in the esthetic zone. Bilateral Class I molar relationship was noticed after clinical and good interdigitation at premolar area.

Treatment objective and plan

We planned local orthodontic treatment for leveling and alignment of the anterior teeth before 21 extraction and implant reconstruction.

Treatment progress

The angular bony defect at distal side of 21 was due to the tooth structure defect which violate the biological width. Generally, the patient had proper oral hygiene and the gingival color was in coral pink. There were no plaque and calculus between 21 and 22, and we decided to start orthodontic extrusion without periodontal phase I treatment.

The orthodontist tried to improve the implant site before extracting 21 by slow orthodontic extrusion. The mechanical design of the orthodontic appliance was 0.016-inch SSW round wire with a step-down bend at #21, accompanied by vertical elastics on the neighboring teeth to eliminate intrusive force (Figure 2, left).

The extrusion rate of SOE is no more than 2mm per month and stabilization is no less than one month for every month of activation. Atherton’s patch (red patch) was usually noticed after SOE procedure, it is the stretch of gingival sulcus in the direction of orthodontic tooth movement, and the non-keratinized epithelium from inner
side of gingival sulcus will keratinized in 28 days, this is why SOE procedure can increase the width of keratinized gingiva. After 3.5 months of slow orthodontic extrusion (Figure 2, right), the periodontist performed extraction of 21 (Figure 3, left) and immediate implantation. A 3.3x10 mm Straumann® Bone Level Implant fixture was inserted in the extraction socket (Figure 3, right), followed by guided bone regeneration with a Ti-reinforced Gore-Tex non-absorbable membrane (Figure 4). At the same time, a connective tissue graft harvested from the palatal side was sutured under the labial flap. Following periosteal release, the flap was closed with Gore-Tex sutures (Figure 5). Eight months after implant surgery, a second stage surgery to remove the non-absorbable membrane was performed along with a connective tissue graft to increase soft tissue thickness (Figure 6).

**Treatment result**

The effects of SOE of this case are: improvement of the gingival height at mid-facial aspect of 21, correction of the angular bony defect between 21 & 22 and made an immediate implant placement possible.

One year and eight months after implant surgery, the treatment results were stable. This interdisciplinary approach produced good esthetic results with an implant prosthetic in the esthetic zone at the anterior maxilla (Figure 7).
**DISCUSSION**

1. Use of SOE to prepare the implant site according to surgeons’ expectations

Using SOE to improve the condition of the implant site, we should consider the specific criteria necessary for immediate implant placement in the esthetic zone at the anterior maxilla, in particular, the thickness and height of the labial bone plate.

![Figure 5](image1)

**Figure 5.** Left, a c.t. graft harvested from palatal side was sutured under the labial flap; right, the flap was primary closed after periosteal releasing.

![Figure 6](image2)

**Figure 6.** Left, second stage surgery, the non-resorbable membrane was removed, good treatment result of GBR was noticed; right, a c.t. graft harvested from palatal side to increase soft tissue thickness.

Immediate and early implant placement at the anterior maxilla requires clinical experience and good technique, as well as appropriate selection of cases, according to the 2014 consensus statements by the International Team for Implantology. The criteria for immediate implantation at the anterior maxilla are: an intact socket wall, facial bone wall at least 1 mm in thickness, thick soft tissue, no acute infection at the site, and bone availability apical and palatal to the socket in order to provide primary stability.

![Figure 7](image3)

**Figure 7.** Left, before treatment; middle, after 3.5 months of 21 SOE; right, 1y8m after implant surgery.
Preoperative cone beam computed tomography (CBCT) is required to obtain the correct 3D positioning of the implant fixture and to ensure that 2 mm of bone at the labial side of the implant fixture remains after surgery and post-surgical bone resorption. To maintain the esthetics of the implant at the anterior maxilla, it is key to have ideal thickness of the labial bone plate at 3 mm below the estimated gingival margin or CEJ of the adjacent tooth at the mid-facial point.

During SOE along the long axis of the root, light continuous force provides tension between the entire root surface and the inner side of the socket, producing the maximum new bone formation without jeopardizing the original labial bone plate. In addition to filling the extraction socket with bone, the periodontal attachment level of the root remains unchanged during the SOE process. If there is no inflammation caused by poor oral hygiene, additional new bone will form in the vertical direction at the attachment level between the hopeless tooth and the adjacent teeth. More specifically, bone and periodontal attachment around the hopeless/erupted tooth move coronally, while the interproximal bone level of the adjacent teeth remains about unchanged, unless they are coronally erupted at the same time. When this newly formed osteoid tissue exceeds the bone crest of the adjacent teeth, it will be absorbed along with the bundle bone following extraction. This is the reason why SOE increases the bone height only to the level of, and never exceeding, the interdental bone crest of the adjacent teeth.

Some clinicians have asked if SOE can increase bone volume at the buccal side, if root torque is exerted to move the root out of the buccal bone plate. In fact, excessive buccal root torque will break the integrity of the buccal bone plate. Before tooth extraction, intentional root torque results in new bone formation between the tension side of the PDL at the palatal/lingual side of the root surface and the original bone contour surface. Once the root is removed, any osteoid tissue exceeding the original buccal contour between the bone surface and the PDL will be absorbed. In addition, the distance between the most prominent points of the adjacent teeth at the buccal side is normally wider than the interdental bone crests of the adjacent teeth. It is difficult to effectively augment ridges laterally using this small, newly formed osteoid tissue at the tension side of the root PDL.

Once we understand where we can use SOE to generate new bone in the esthetic zone at the anterior maxilla and the specific conditions required for immediate implantation, we can design proper mechanics to create new bone where it is needed to meet surgeons’ expectations for preparing the implant site.

2. A brief review of SOE case reports

We used the PubMed electronic database for our review, using keywords relevant to this technique and the medical subject headings provided by PubMed: force eruption, implant site. The period searched was from 1993 to 2017 and the language of the search was limited to English. The journal articles we collected consisted mainly of case reports and case series. Articles related to SOE were retrieved from the database and we searched them manually to identify relevant case reports and case series from the references obtained. Journals that are no longer published and articles that cannot be obtained online were excluded. We also excluded individual clinical case studies published on the Internet that were not published in journals. Lastly, articles discussing SOE methods that lacked complete description of clinical cases were also excluded. The keyword search yielded 35 articles from 1993 to 2017. After filtering through the exclusion and inclusion criteria and performing the manual search, we found a total of 19 case reports and case series on SOE that were suitable for review.

We reviewed and organized these 19 articles for this article (Table 1). We reorganized their content according to the following categories: tooth position, reason for extraction, active SOE treatment and stabilization time (total treatment time), force eruption mechanics (round wire or rectangular wire, representing...
whether the direction of root movement was being controlled), amount of orthodontic extrusion, surgical method (mainly flap surgery or flap-less surgery, and whether or not GBR surgery was performed simultaneously with the implant surgery). In addition, to determine whether the information in these records was sufficient for identifying changes induced by SOE in the 3D topography of the bone, we laid out the treatment progress records for these case reports and case series and listed the following items for comparison: initial clinical photos, initial periapical x ray films, initial CBCT, clinical photos after SOE, periapical X-ray film after SOE, CBCT after SOE, surgery photos, post implant X-ray films, and post implant clinical photos. Details are shown in Table 1.

3. Relating orthodontic appliance design to the location for new bone formation

Eleven of the articles reviewed in Table 1 employed round wires or elastic materials, implying uncontrolled labial root movement.

One article described a full mouth fixed orthodontic treatment, but did not mention the design of the extrusion mechanics, while seven papers used rectangular wires for orthodontic extrusion to effectively control the direction of root movement during SOE.

Since light continuous force is needed to direct new bone formation at the tension side, most of the cases in these articles used round wires rather than rectangular wires, since rectangular wires usually produce heavier force even with little activation. However, the direction of root movement cannot be effectively controlled with round wire. Extrusion with round wire from the labial side will result in uncontrolled labial root tipping and resorption of labial bone plate over time (Figure

<table>
<thead>
<tr>
<th>tooth position/ reason for extraction</th>
<th>active tx &amp; stabilization time / total orthodontic treatment time</th>
<th>orthodontic appliance/ extrusion distance</th>
<th>surgical method</th>
<th>data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salama</td>
<td>Multiple teeth</td>
<td>Elastics from post</td>
<td>All flap surgery with GBR</td>
<td>(O) initial clinical photo (O) initial periapical x ray film (O/X) initial CT (for two teeth) (O) after FOE clinical photo (O) after FOE periodical x ray film (O/X) after FOE CT (for two teeth) (O) surgery photo all case received GBR when implant surgery (O) post implant x ray (O/X) post implant clinical photo (one single implant between two nature teeth)</td>
</tr>
<tr>
<td>2. Mantzikos, T. et.al. 1998</td>
<td>#11,#21/periodonti-tis</td>
<td>6 months ex-trusion + 4-6 months fixation / 12 months</td>
<td>round wire / 7-8 mm bone (5 mm keratinized gingiva)</td>
<td>4 week after extraction implant surgery with GBR (X) initial clinical photo (O) initial periapical x ray film (X) initial CBCT (O) after FOE clinical photo (O) after FOE periodical x ray film (X) after FOE CBCT (O) surgery photo (O) post implant x ray (X) post implant clinical photo</td>
</tr>
<tr>
<td>3. Mantzikos, T. et.al. 1999</td>
<td>#11,#21/five patients/periodonti-tis</td>
<td>12 weeks + 12 weeks stabilization / 6 months</td>
<td>round wire / mean 8.7mm</td>
<td>immediate implantation with flap reflection (O) initial clinical photo (O) initial periapical x ray film (X) initial CBCT (O) after FOE clinical photo (O) after FOE periodical x ray film (X) after FOE CBCT (O) surgery photo (O) post implant x ray (X) post implant clinical photo</td>
</tr>
<tr>
<td>Study (Year)</td>
<td>#</td>
<td>Description</td>
<td>Orthodontic Details</td>
<td>Surgical Details</td>
</tr>
<tr>
<td>-------------</td>
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</tr>
<tr>
<td>4. Nozawa, T., et al. (2003)</td>
<td>#35</td>
<td>periodontitis</td>
<td>90° buccal root torque / 15 mm (non-conventional orthodontic tooth movement)</td>
<td>FGG during stabilization period</td>
</tr>
<tr>
<td>5. Zuccati, G. et al. (2003)</td>
<td>#21</td>
<td>trauma history</td>
<td>Rectangular wire with BRT</td>
<td>Implant surgery after 2 months of extraction / Small fenestration, not an immediate implantation,</td>
</tr>
<tr>
<td>6. Hinds, K. et al. (2005)</td>
<td>#21</td>
<td>periodontitis</td>
<td>Rectangular wire / 6-7mm: #21 / 2-3mm: #22 / #21,22 force extrusion to raise interdental bone height</td>
<td>Immediate implantation</td>
</tr>
<tr>
<td>7. Park, Y.S., et al. (2005)</td>
<td>#21</td>
<td>periodontitis</td>
<td>Round Ni-Ti wire / not available</td>
<td>Flap reflection, immediate provisionalization</td>
</tr>
<tr>
<td>8. Chambrone, L. et al. (2005)</td>
<td>#12</td>
<td>fracture</td>
<td>0.016 Ni-Ti wire / not available</td>
<td>Immediate implantation</td>
</tr>
<tr>
<td>9. Gonzalez Lopez, S. et al. (2005)</td>
<td>#11</td>
<td>external root resorption</td>
<td>Elastics / not available</td>
<td>2 weeks after extraction / Flap reflection / Palatal flap vestibular displacement</td>
</tr>
<tr>
<td>10. Lin, C.D., et al. (2006)</td>
<td>#11</td>
<td>periodontitis</td>
<td>2 months</td>
<td>Flapless immediate implantation with none GBR / Extraction socket being filled thoroughly, bony defect completely disappeared</td>
</tr>
</tbody>
</table>

**Table 1:** Orthodontic Extrusion for Implant Site Preparation
2007 | #21  
/ dental caries | 1 month extrusion  
+ 3 months stabilization  
/ 4 months | round wire  
/ not available | flapless implantation with immediate provisionalization  
(O) initial clinical photo  
(O) initial periapical x ray film  
(X) initial CBCT  
(O) after FOE clinical photo  
(X) after FOE periodical x ray film  
(X) after FOE CBCT  
(X) surgery photo  
(O) post implant x ray  
(O) post implant clinical photo |
2010 | #12,11,  
#21,22  
/ generalized aggressive periodontitis | 15 months | round wire  
/ not available | flap reflection immediate implantation at i12,i22, no GBR  
(O) initial clinical photo  
(O) initial periapical x ray film  
(X) initial CBCT  
(O) after FOE clinical photo  
(X) after FOE periodical x ray film  
(X) after FOE CBCT  
(O) surgery photo (occlusal view)  
(O) post implant x ray  
(O) post implant clinical photo |
2011 | #11 | 70-100g  
6 months | lingual button & elastics to occlusal splint  
improve #12,i11 interdental bone crest | 6 weeks after #11 extraction  
(total 7.5 months), flapless surgery  
(O) initial clinical photo  
(O) initial periapical x ray film  
(X) initial CBCT  
(O) after FOE clinical photo  
(X) after FOE periodical x ray film  
(X) after FOE CBCT  
(O) surgery photo (labial bony defect)  
(O) post implant x ray  
(O) post implant clinical photo |
2012 | #11,#21  
/ periodontitis | 3 months | rectangular wire  
no torque control  
/ not available | immediate implantation with simultaneous GBR  
/palatal flap buccally positioned when 2nd stage  
(O) initial clinical photo  
(O) initial periapical x ray film  
(X) initial CBCT  
(O) after FOE clinical photo  
(X) after FOE periodical x ray film  
(X) after FOE CBCT  
(O) surgery photo (occlusal view, flapless)  
(O) post implant x ray  
(O) post implant clinical photo |
2012 | #12,11,21,22  
/ periodontitis | 4 months  
+ 4 months stabilization | Multi-strain round wire  
/ 2-4mm | flapless implantation one months after extraction  
(socket preservation)  
(O) initial clinical photo  
(O) initial periapical x ray film  
(O) initial Tomo  
(X) after FOE clinical photo  
(X) after FOE periodical x ray film  
(O) after FOE Tomo  
(X) surgery photo  
(O) post implant x ray  
(O) post implant clinical photo |
| 16. | Watanabe, T. et al.  
2013 | #21  
/ periodontitis | 5 months | rectangular wire with palatal inset  
/ 6-7 mm | flap reflection with GBR at buccal side  
(O) initial clinical photo  
(O) initial periapical x ray film  
(X) initial CBCT  
(O) after FOE clinical photo  
(O) after FOE periodical x ray film  
(X) after FOE CBCT  
(O) surgery photo (labial bony defect)  
(X) post implant x ray  
(O) post implant clinical photo (4 years f/u CBCT) |
| 17. | de Molon, R.S., et al.  
2013 | #12  
/ periodontitis | 3 months extrusion  
+ 4 months stabilization  
/ 7 months | round wire  
(pc from post)  
/ not available | flap reflection w/o GBR  
(O) initial clinical photo  
(O) initial periapical x ray film  
(X) initial CBCT  
(O) after FOE clinical photo  
#24 gingival recession  
(O) after FOE periodical x ray film  
(X) after FOE CBCT  
(O) surgery photo (only occlusal view)  
(O) post implant x ray  
(O) post implant clinical photo |
Slow Orthodontic Extrusion for Implant Site Preparation

8, middle), which is detrimental to the esthetics of the implants at the anterior maxilla. Therefore, although the extraction socket fills with new bone during the SOE process, the net results could still lead to dehiscence or fenestration of the labial plate (Figure 3, right). This is the reason why some SOE cases still require simultaneous GBR during implant surgery (Figure 4). On the other hand, if rectangular wires are used for better root torque control, it is hard to measure the moment that labial root tipping begins in order to counter it completely. If we cannot create ideal conditions of the labial bone plate, GBR is still necessary. SOE is a technique-sensitive procedure to meet the special requirements for immediate implantation at the anterior maxilla, specifically in terms of the thickness and height of the labial bone plate.

The interdental bone crest height between the implant fixture and the neighboring teeth is also important for the implant esthetic at the anterior maxilla. Using SOE to extrude the hopeless tooth and its neighboring teeth can raise the height of the interdental bone between the hopeless tooth and neighboring teeth and improve the interdental papilla height between the planned implant and its neighboring teeth. This is a unique advantage offered by SOE that regenerative surgery cannot provide.

4. The benefits of SOE for implant site preparation in the esthetic zone at the anterior maxilla

If severe bony defects are present which call for staged GBR before implant surgery, SOE can decrease the size of the extraction socket, converting a severe bony defect into a moderate bony defect. This situation is one of the indications for SOE. Use of SOE in such circumstances makes implant surgery with simultaneous GBR possible and increases the primary stability of the implant fixture. However, we need to compare the costs and benefits between SOE and staged GBR surgery,

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**Figure 8.** Left, CBCT at 21 area before SOE, thin labial bone plate was noticed; middle, CBCT at 21 area after SOE, labial root tipping causes resorption of labial plate; right, CBCT at implant site 1y8m after implant surgery, the thickness of labial plate is the result of GBR.
considering the number of outpatient visits, treatment costs, predictability of treatment outcomes, esthetic concerns during the SOE process, and treatment time. It is important to analyze the advantages and disadvantages of these two methods, to explain them to patients, and to choose a strategy that fits their needs.

SOE is recommended for developing the implant site by transforming moderate bony defects into incipient bony defects, which can then be followed by extraction and immediate implantation. The value of this non-surgical technique is to eliminate at least one surgical procedure for implant therapy such as staged GBR procedures, implant surgery without the need for simultaneous GBR surgery, or muco-gingival surgery. It should be carefully evaluated whether a satisfactory clinical endpoint which allow a minimally invasive immediate implant procedure can be achieved, or the procedure should not be performed before implant surgery.

5. Determining the effectiveness of SOE

Since SOE was first proposed in 1993, both orthodontists and periodontists have had high expectations for this interdisciplinary treatment, hoping to achieve better implant esthetics at the anterior maxilla. However, the results of SOE treatment have mostly been presented in clinical case reports, making it hard to compare outcomes of SOE with GBR. In this study, we analyzed case reports and case series involving SOE, comparing the orthodontic appliances used, the location of new bone formation, and evaluating resulting alveolar bone condition at the implant site. However, the data provided by these clinical cases are not sufficient for us to definitively determine the effectiveness of SOE.

To evaluate SOE outcomes, it would be ideal to analyze CBCT images before and after SOE procedures (Figure 8). The case reports in Table 1 all showed good treatment outcomes; of these, 14 articles included surgery photos. However, these papers did not provide any information regarding bone morphology before and after SOE, and therefore it is hard to be certain of the changes obtained via SOE at the implant site. The lack of appropriate data is why no one has been able to objectively compare the efficacy of SOE and GBR.

While reviewing these case reports, we paid special attention to the condition of the labial bone plates during post-SOE implant surgery. There were four flapless implant surgery cases and two cases without surgical photos described as flapless implant surgery, consequently the labial bone plates could not be observed. There were also five cases of implant surgery with simultaneous GBR. Four more papers described patients who received implant surgery without GBR surgery.

Ultimately, we were unable to determine the differences in 3D hard tissue topography before and after SOE based on current clinical reports. Collection of clinical data at every step is needed to analyze the changes obtained by SOE and to confirm the effectiveness of this procedure; without it, we cannot attribute good clinical outcomes to SOE.

The first bone regeneration in conjunction with the placement of dental implants was introduced by Nyman in 1991. Periodontists have attempted to correct various type of bony defects and to improve the conditions at the implant site and thereby achieved better outcomes for implant therapy.

SOE, a non-surgical technique, was designed by Salama to improve the 3D topography of bony defect at the implant site in 1993—almost the same period, with the same purpose. Since Nyman’s initial study, there has been considerable progress in implant therapy, including improvements in implant fixture design, surface treatment of the implant fixture, understanding implant fixture diameter at the anterior maxilla, surgical techniques, as well as improved bone graft material and membrane material. Thus, the predictability of surgical treatment outcomes of GBR surgeries today has greatly improved from that time. Orthodontists need to evaluate the treatment efficacy and the benefits of SOE from various
angles; then we can provide informed opinions and provide better service to our collaborating surgeons and patients.

CONCLUSION

1. Slow orthodontic extrusion along the axis of the root can induce maximal new bone formation. Even if newly formed bone at the attachment level of the root exceeds the interdental bone crest height of the adjacent teeth, that newly formed osteoid tissue will be absorbed after extraction.\textsuperscript{5,12,13,14} We are unable to confirm that SOE is effective for lateral ridge augmentation.

2. SOE is a non-surgical method which can transform a severe bony defect requiring staged GBR surgery into a moderate bony defect which can be treated with implant surgery and simultaneous GBR. However, we need to consider the treatment time, costs, number of follow-up outpatient visits, and esthetic concerns during treatment, as well as compare the predictability of treatment outcomes for SOE and staged GBR surgery.

4. Use of SOE for implant site preparation in the esthetic zone at the anterior maxilla has the greatest benefit when used to correct a moderate bony defect and followed by a minimally invasive surgical procedure for immediate implant placement.

5. Extrude the hopeless tooth and its neighboring teeth simultaneously can raise the interdental bone height between the hopeless tooth and its neighboring teeth and improving the interdental papilla height between the implant and its neighboring teeth are unique advantages of SOE that cannot be achieved by regenerative surgery.\textsuperscript{21} However, reduction of the incisal edge of the neighboring teeth is needed following the extrusion procedure in order to create adequate incisal relationship.

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