

Implant Site Development by Orthodontic Forced Extraction: A Preliminary Study

Francesco Amato, MD, DDS, PhD¹/A. Davide Mirabella, DDS, MSD²/
Ugo Macca, DDS³/Dennis P. Tarnow, DDS⁴

Purpose: To evaluate the soft and hard tissue response to orthodontic implant site development (OISD) (ie, forced extraction), to measure the amount of tissue that was regenerated and its relationship to the amount of orthodontic vertical tooth movement, to evaluate the tissue response in teeth with different degrees of periodontal attachment loss, to understand the limits of OISD, and to evaluate the implant survival rate. **Materials and Methods:** A total of 32 hopeless teeth were treated with OISD, and 27 implants were placed in 13 patients consecutively. The level of periodontal attachment on the teeth to be extracted, amount of augmented alveolar bone, changes in soft tissue volume, and the rate of orthodontic tooth movement were recorded. **Results:** Mean values after OISD were as follows: orthodontic extrusive movement, 6.2 ± 1.4 mm; bone augmentation, 4 ± 1.4 mm; coronal movement of the gingival margin, 3.9 ± 1.5 mm; coronal movement of the mucogingival junction, 2.1 ± 1.3 mm; keratinized gingival augmentation, 1.8 ± 1.1 mm; gingival thickness (buccolingual dimension) augmentation, 0.7 ± 0.4 mm; recession, 1.8 ± 1.2 mm; bone augmentation/orthodontic movement ratio (efficacy), $68.9\% \pm 17.3\%$; gingival augmentation/orthodontic movement ratio (efficacy), $65.2\% \pm 19.9\%$; and pocket depth reduction, 1.8 ± 0.9 mm. The implant survival rate was 96.3%. **Conclusions:** OISD was a viable treatment for these hopeless teeth to regenerate hard and soft tissues. Its efficacy was about 70% for bone regeneration and 60% for gingival augmentation. The residual attachment level on the tooth was not a limitation. OISD might be a valuable treatment option to regenerate tissues for implant site development in patients in need of conventional orthodontic therapy. *INT J ORAL MAXILLOFAC IMPLANTS* 2012;27:411–420

Key words: bone augmentation, forced eruption, gingiva augmentation, implant site development, orthodontic forced extrusion, orthodontic implant site development

Implant-supported prostheses are a viable solution to replace missing teeth, since osseointegration has been shown to be predictable, with a 96% long-term success rate.¹ In the anterior segment, there are still many concerns regarding esthetic results, especially in cases of single tooth replacement, where the contralateral natural tooth acts as a mirror image for the crown on the implant.² Many authors have reported a high incidence of discrepancies in gingival margin levels between an implant crown and the contralateral natural tooth.^{3,4} This sometimes can be explained by

an incorrect three-dimensional position of the head of the implant, especially buccolingually,⁵ but more often it is caused by a lack of hard and soft tissue. It is important to understand that after the tooth is extracted, the alveolar bone and soft tissues remodel, with a consequent reduction in site volume in the vertical and horizontal dimensions.^{6–8} There is also ample evidence that insertion of an implant into a fresh extraction socket does not prevent alveolar bone resorption,^{9–11} regardless of whether a crown is placed immediately or after a delay.^{3,12–13}

Because tooth extraction is always followed by some crestal bone loss, mostly involving the buccal plate, it is vital to maintain the level of the vestibular gingival margin on the future implant crown.⁷ To achieve favorable esthetic results, surgical procedures to preserve or to reconstruct hard and soft tissues have been proposed, but the outcome is not always predictable.^{14,15} A clinical alternative to regenerate hard and soft tissues for implant site development is orthodontic forced eruption (OFE) or orthodontic implant site development (OISD), a technique described by Salama and Salama, to reconstruct the implant site.¹⁶

¹Private Practice, Catania, Italy.

²Adjunct Professor, Department of Orthodontics, University of Ferrara, Italy; Private Practice, Catania, Italy.

³Private Practice, Siracusa, Italy.

⁴Clinical Professor and Director of Implant Education, Columbia University College of Dental Medicine, New York, New York; Private Practice, New York, New York.

Correspondence to: Dr Francesco Amato, Viale A. De Gasperi 187, Catania, Italy. Fax +39-095388585. Email: dr.amatofrancesco@libero.it

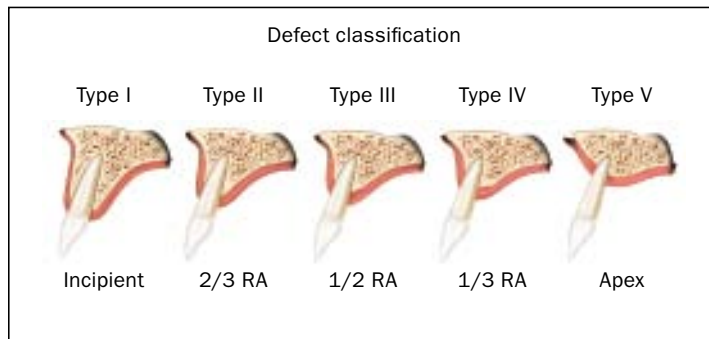


Fig 1 Defect classification based on the amount of residual attachment (RA). Type I = no bone loss; type II = residual attachment covers two-thirds of the root; type III = residual attachment covers half of the root; type IV = residual attachment covers one-third of the root; type V = only a few millimeters of residual attachment are present around the root apex.

Orthodontic treatment can also treat some clinical difficulties that cannot be solved by surgery alone: the mesiodistal dimension of the edentulous space, root proximity, positions and periodontal topography of the teeth adjacent to the edentulous area, and occlusal pattern.¹⁷

The purpose of this study is to evaluate the soft and hard tissue response to OISD, to measure the amount of tissue regeneration, to evaluate the clinical indications for different degrees of periodontal attachment loss on the extruded tooth, to understand the limits of the procedure, and to evaluate the implant survival rate in areas where OISD was performed.

MATERIALS AND METHODS

From March 2004 until December 2009, patients in need of conventional orthodontic therapy to correct malocclusion and esthetics, and who needed to have one or more teeth extracted for future implant placement or pontic areas, were included in this study. A total of 32 teeth in 13 consecutively treated patients were extracted by means of orthodontic forced eruption; 27 were replaced by implants and 5 were replaced by pontics.

Both smokers and nonsmokers were included in this study; patients with systemic disorders were excluded from the study because of contraindications to any surgical treatment. Teeth that needed to be extracted had been diagnosed as hopeless because of periodontal disease, caries, tooth fracture, or any other cause that prevented tooth restoration.

A previous classification¹⁶ had created three categories of bone defects. To better analyze the responses of hard and soft tissues in different clinical scenarios and to provide a reproducible standardized clinical application, two new categories were added that have, to date, not been investigated thoroughly: type I, which includes cases of no bone loss where OFE was used to overbuild the site to compensate for expected post-extraction remodeling, and type V, which includes cas-

es of extreme bone loss up to the apex of the root. A new classification of the alveolar bone defect based on the percentage of the residual alveolar attachment on the root is proposed, and all the teeth included in this research protocol were classified into five categories (Fig 1) according to their residual periodontal attachment and alveolar bone level (Table 1).

Treatment followed the following course: defect diagnosis, periodontal treatment, root canal therapy, OFE, tooth extraction, flapless immediate implant placement with immediate provisionalization, tissue conditioning with new provisional prostheses for at least 6 months, and delivery of the definitive restoration (Fig 2).

The diagnosis of the defects was obtained with periapical radiographs, periodontal and bone probing around the tooth and the adjacent teeth, biotype analysis, measurement of the width (distance from the gingival margin to the mucogingival junction [MGJ]) and thickness (distance between the outer surface of the gingiva and the underlying alveolar bone) of the keratinized gingiva (KG), and assessment of gingival recession (Fig 2). Based on the results, the teeth were identified and classified in one of the five defect types.

Periapical radiographs and all measurements of the involved tooth and of the adjacent teeth were obtained and recorded before periodontal treatment (T-0) (Fig 2a); 2 months after periodontal treatment, at the beginning of orthodontic treatment (T-1) (Figs 2b and 2d); during orthodontic treatment at 1-month intervals (T-n); on the day of extraction and implant insertion (T-end) (Figs 2c and 2e); and at 6-month intervals thereafter. For each patient, a landmark was identified that would be stable during treatment and therefore could act as a reference point to measure the movement of the tooth and alveolar bone during treatment (eg, floor of the nose, root apex of an adjacent tooth that was not involved in orthodontic alignment) and the bone level. When possible, a computed tomographic scan was obtained.

The biotype was analyzed by inserting a probe inside the sulcus of the tooth midbuccally and defining the

Table 1 Patient Characteristics

Patient	Sex	Smoke	Tooth no. (FDI)	Defect class	Reason for extraction	Implant type
1	F	Y	11	IV	Perio	NT413
			12	II	Perio	NT413
			22	III	Perio	NT413
2	F	N	21	I	Nonrest	NT511
3	M	Y	15	I	Nonrest	NT511
4	M	Y	22	IV	Perio	NT413
			23	III	Perio	NT413
			24	V	Perio	OSS413
			25	V	Perio	OSS411
			26	IV	Perio	OSS411
5	F	N	12	V	Perio	NTP413
			22	V	Perio	NTP413
6	F	Y	12	V	Perio	NTP3213
7	F	Y	11	III	Perio	NT411
			21	III	Perio	Pontic
			22	III	Perio	NT411
8	M	Y	12	IV	Perio	NIITP4311
			11	IV	Perio	NT511
			22	IV	Perio	NIITP4311
9	F	Y	12	V	Perio	NITP4313
			11	V	Perio	Pontic
			21	V	Perio	Pontic
			22	V	Perio	NITP4313
			32	IV	Perio	NNT3213
			31	IV	Perio	Pontic
			41	IV	Perio	Pontic
			42	IV	Perio	NNT3213
10	F	Y	21	V	Perio	NT415
11	F	N	21	III	Caries	NTPCP5411
			22	IV	Perio/endo	NT3211
12	F	Y	23	IV	Perio	NT413
13	F	Y	13	II	Nonrest	NT410

See Fig 1 for further information on defect classifications.

Perio = periodontitis; endo = endodontic failure; nonrest = nonrestorable.

NT = Natural Tapered (conical); OSS = Osseotite (cylindrical); NTP/NTPCP = Natural Tapered Prevail;

NIITP/NITP = Natural Tapered Internal Connection; NNT = Nanotite Natural Tapered.

tissue as a thick or thin biotype.¹⁸ Following an initial general classification, the gingival thickness was recorded to a more detailed level; after anesthesia was obtained, the probe was inserted midbuccally at a 90-degree angle to the long axis of the tooth until it reached the bone/root surface at 3 mm apical to the free gingival margin. The gingival biotype was measured at the beginning and the end of orthodontic treatment.

The amount of KG and gingival recession were also measured. The presence and volume of the papillae were recorded; the distance between the tip and the contact point was measured and classified using the Jemt score.¹⁹

The treatment of hopeless teeth began with root canal therapy to eliminate any sensitivity following periodontal treatment or occlusal reduction. Periodontal

treatment followed according to probing depth. Teeth with pocket depths ranging between 1 and 5 mm were treated with scaling and root planing in combination with topical antibacterial treatment (chlorhexidine 0.1% rinse three times daily). Teeth with pockets that were 5 mm or deeper were treated with scaling and root planing in combination with topical antibacterial treatment; this was followed 1 month later by an open flap debridement (modified Widman flap) in combination with topical antibacterial treatment (chlorhexidine 0.2% three times daily for 2 weeks).

Immediately after periodontal treatment, orthodontic brackets were applied, and tooth alignment was obtained with a 0.016-inch heat-activated nickel-titanium archwire. Following this, a 0.018-inch stainless steel archwire was placed, and 1-mm vertical-forward steps



Fig 2a Maxillary right lateral incisor before periodontal treatment (T-0).



Fig 2b Maxillary right lateral incisor 1 week after periodontal treatment, at the beginning of orthodontic extrusion (T-1).



Fig 2c Maxillary right lateral incisor at the end of orthodontic extrusion (T-end).



Fig 2d Periapical radiograph of the tooth showing bone level at the beginning of orthodontic extrusion.



Fig 2e Periapical radiograph of the tooth showing the amount of newly formed bone after orthodontic extrusion.



Fig 2f Periapical radiograph at the time of implant placement shows a great amount of basal bone engaged by the implant.



Fig 2g Clinical view at time zero (T-0) 1 week after periodontal surgery just before placement of brackets.



Fig 2h Clinical view of the definitive crowns on both lateral incisors. Also note the coronal migration of the gingival margins on the central incisors (the "blanket effect").

were bent to obtain 1 mm of extrusion along the tooth's long axis at each activation. Alternatively, a 0.019- × 0.025-inch beta-titanium archwire with a 1-mm vertical step and palatal root torque was used. The bends were deepened at each appointment at 1-month intervals. It was assumed that the amount of extrusion would be equal to the total millimeters of activation.

During treatment, patients were monitored every other week to ensure that the extruded tooth was kept out of occlusion and to confirm good hygienic conditions in the area to prevent inflammation. At each visit, the incisal edge of the tooth was ground with a diamond bur (1 or 2 mm each time), and the amount of shortening was recorded. Periapical radiographs were obtained at

1-month intervals to measure the alveolar bone movement. Periodontal records were also collected to detect any new tissue changes that may have occurred.

The decision to end extrusion was based on the observation of the new bone level. The goal was to exceed by at least 2 mm the bone level of the contralateral tooth, which acted as a reference. After the site was well developed, a period of 2 months of orthodontic stabilization was applied to allow mineralization of the newly formed bone matrix. The patient was then sent for a computed tomographic scan. All the clinical measurements that had been recorded at the beginning of treatment were repeated at this time.

Two days before implant placement, a final, rapid extrusive force was applied to the extruded tooth/teeth. This helped to widen the periodontal ligament space of the root and would make extraction of the tooth easier and less traumatic.

The patient was prescribed antibiotic prophylaxis (amoxicillin tablets, 1 g every 12 hours) and antibacterial mouth rinse (chlorhexidine 0.2%) starting 24 hours before surgery.

On the day of the surgery, all clinical data were recorded once again (probing depth, etc).

All teeth were extracted without raising a flap. In 11 patients, 27 teeth were replaced by implants. All but three implants were conical in shape (14 Osseotite, 13 Nanotite, Biomet 3i) (Table 1). In two patients, five extruded teeth were replaced by pontics to optimize esthetics in a four-unit fixed partial denture supported by two implants, to replace the four incisors. The implants were inserted flapless, the provisional abutments were connected, and the screw-retained provisional crowns were placed out of occlusion. Tapered implants (NT Osseotite/Nanotite, Biomet 3i) were inserted with a minimum torque of 40 Ncm (Fig 2f).

When a gap was present between the implant and the alveolar bone plate on the facial side after implant placement, autologous bone chips or nonresorbable bone substitute particles (Bio-Oss, Geistlich Pharma) were placed into the buccal gap between the implant and the buccal wall of the extraction socket to provide a solid scaffold for blood clot formation.²⁰ Once again, no flap was raised and no attempt was made to achieve primary closure with sutures.

Whenever possible, a prosthetic platform that was narrower than the implant head (ie, platform switching) was used to reduce bone resorption around the implant.^{21,22} In almost all cases, a screw-retained provisional restoration was preferred. The abutment screw was torqued at 20 Ncm with a calibrated torque driver (Biomet 3i). The crown was left out of occlusion in both centric and noncentric relationships. A final periapical radiograph was obtained. The patient was sent home and instructed to stay on a liquid diet for 1 week and

not to chew on the new provisional crown for a minimum of 6 weeks. After 8 weeks, the provisional was removed for tissue conditioning. The provisional crown was then left in place for at least 4 months to allow maturation and stabilization of the soft tissue contours. At least 6 months were allowed to elapse before final impressions were made. To replicate the dimensions of the implant sulcus, a customized coping was used.²³

To maximize the final esthetic result, zirconia abutments and all-ceramic crowns were used (Figs 2g and 2h).

Data Analysis

The following measurements were calculated and recorded.

- Amount of orthodontic extrusion (OE)
- Amount of bone augmentation per extruded tooth (BA)
- Amount of keratinized gingiva augmentation (KGA) (vertical augmentation of the keratinized width)
- Movement of the MGJ (MGJM)
- Amount of gingival augmentation per extruded tooth (GA) (coronal movement of the gingival margin)
- Amount of recession occurred during orthodontic treatment (R)
- Changes in gingival thickness on the facial side (GTA)
- Pocket depth reduction during orthodontic extrusion (PDR), ie, the difference between the pocket depth at the end of orthodontic extrusion (PDT2) and the pocket depth at the beginning of orthodontic extrusion (2 months after periodontal treatment) (PDT1)
- Efficacy of the orthodontic vertical movement in creating new bone, defined as the percentage of bone generated with respect to the amount of orthodontic vertical movement (bone augmentation/amount of orthodontic movement ratio; BA/OE %)
- Efficacy of the orthodontic vertical movement in creating new soft tissue, defined as the percentage of gingiva generated with respect to the amount of orthodontic vertical movement (gingival augmentation/amount of orthodontic movement ratio; GA/OE %)
- Changes in papillae height

The Kruskal-Wallis test was used to test the hypothesis that there was no difference between the amount of BA/OE% among the five classes of defects.

RESULTS

Table 2 presents the results in detail for each patient. The implant survival rate, during a follow-up period ranging from 18 to 61 months, was 96.3% (1 of 27 implants failed). Table 3 presents the overall average clinical changes.

Table 2 Results of OISD by Patient

Patient	Tooth no.	OE (mm)	BA (mm)	KGA (mm)	MGJM (mm)	GA (mm)	R (mm)	GTA (mm)	PDT2 (mm)
2	21	4	3.1	2.9	1.4	3.1	0.2	0.7	1
4	22	7	4.1	1.3	5	6.3	0.9	0.4	1
	23	7	6	1.1	5	6.1	2.5	0.3	1
	24	6	4	1.9	4	5.9	1.1	0.1	2
	25	7	4.7	3.4	3	6.4	1.4	0.7	2
	26	7	3.7	2.2	2	4.4	1	1	3
1	11	7	5.7	3.8	1.8	5.6	2	0.3	2
	21	6	4.9	3.2	1.3	4.5	1.5	0.8	2
	22	6	4.7	2.2	1.2	3.4	2	0.7	2
3	15	5	2.5	2.3	1.8	4.1	1	1.2	1
8	11	5	3	-1.5	3.4	1.9	0.5	0.5	1
	12	5	3	1.2	0.5	1.7	0.6	1.3	2
	22	5	4	1.4	1.3	2.7	0.6	0.9	2
6	12	5	3.3	3.7	4	7.7	2	1.7	3
5	12	6	5	3.5	1.1	4.6	2.7	1.2	2
	22	6	3.7	1.6	0.5	2.1	2.6	0.4	2
9	31	6	4.9	1.1	2.1	3.2	1.4	0.3	1
	32	6	4.7	2	2	4	1.4	0.7	1
	41	6	5.8	2	2.7	4.7	1	0.2	1
	42	6	5.6	2	2.3	4.3	3.2	0.6	1
	11	7	4	2	3.4	5.4	2.9	0.3	1
	12	7	4	0	2.4	2.4	2	0.2	1
	21	7	4	1.1	3	4.1	2.9	0.4	1
	22	7	4	0	2.9	2.9	2.8	0.3	1
10	21	10	8	1.5	1.3	2.8	5.7	0.4	3
7	11	10	3.8	1.8	0.4	2.2	2	1.1	2
	21	7	1.7	2	0.6	2.6	1.5	0.3	2
	22	7	0.6	1.8	0.9	2.7	0.4	0.7	2
11	21	6	3.8	0.3	3.3	3.6	4	0.8	1
	22	5	3.4	1	2.6	3.6	2	1.5	1
12	23	4	2.7	2.3	0.3	2.5	0.4	1.1	1
13	13	3	2.1	2	1	3	0.3	0.9	1
Mean		6.2	4.0	1.8	2.1	3.9	1.8	0.7	1.6
SD		1.4	1.4	1.1	1.3	1.5	1.2	0.4	0.7

SD = standard deviation; OE = orthodontic extrusion; BA = bone augmentation; KGA = keratinized gingival augmentation; MGJM = mucogingival junction movement; GA = gingival augmentation; R = recession; GTA = gingival thickness augmentation on the facial side; PDT2 = pocket depth at the end of orthodontic extrusion; PDT1 = pocket depth at the beginning of orthodontic extrusion; PDR = pocket depth reduction; BA/OE% = bone augmentation/amount of orthodontic movement ratio (efficacy); GA/OE% = gingival augmentation/amount of orthodontic movement ratio (efficacy); BA/GA% = bone augmentation/gingival margin ratio.

The results are also presented according to defect classification (Table 4). There was no difference in the amount of BA/OE% among types I, III, IV, and V ($P = .577$). Category II could not be tested, as only one defect met this classification.

DISCUSSION

Changes in bone and gingival vertical levels by OFE have been documented thoroughly.^{24–30} Reitan³¹ showed that orthodontic extrusion of a tooth is associated with stretching of the periodontal fiber bundles

and consequent bone and gingival apposition. More recently, Salama and Salama¹⁶ presented a new procedure that they called “orthodontic extrusive remodeling,” in which hopeless teeth were extruded by a great distance—nearly to the point of extraction—to encourage the formation of a great amount of new hard and soft tissue. Since then, other clinicians have shown that this procedure, also known as “orthodontic extraction” or “forced eruption,” is a valid alternative to surgical implant site development.^{32–40}

However, a recent systematic literature review of OISD pointed out that there are few data about the biologic behavior of the periodontal tissues and clinical

PDT1 (mm)	PDR (mm)	BA/OE%	GA/OE%	BA/GM%
2	1	78	78	100.0
2	1	59	90	65.6
2	1	86	87	98.8
2	0	67	98	68.4
2	0	67	91	73.6
3	0	53	63	84.1
5	3	81	80	101.2
5	3	82	75	109.3
5	3	78	57	136.8
2	1	50	82	61.0
3	2	60	38	157.9
3	1	60	34	176.5
3	1	80	54	148.1
5	2	66	100	66.0
4	2	83	77	107.8
4	2	62	35	177.1
3	2	82	53	154.7
3	2	78	67	116.4
3	2	97	78	124.4
3	2	93	72	129.2
3	2	67	90	74.4
3	2	80	48	166.7
3	2	67	68	98.5
3	2	80	58	137.9
7	4	80	28	285.7
5	3	63	37	170.3
5	3	28	43	65.1
5	3	10	45	22.2
3	2	63	60	105.0
3	2	68	72	94.4
3	2	68	63	107.9
2	1	70	67	104.5
3.4	1.8			
1.2	0.9			

Table 3 Mean Clinical Parameters After OISD in All 27 Patients

Measurement	Mean	SD	Range
OE	6.2	1.4	3 to 10
BA	4	1.4	0.6 to 8
KGA	1.8	1.1	-1.5 to 3.8
MGJM	2.1	1.3	0.4 to 5.0
GA	3.9	1.5	1.7 to 7.7
R	1.8	1.2	0.2 to 5.7
GTA	0.7	0.4	0.2 to 1.7
PDR	1.8	0.9	0 to 4
BA/OE%	68.9	17.3	10 to 97
GA/OE%	65.2	19.9	28 to 100
BA/GA%	115.3	50.0	22.2 to 285.7

SD = standard deviation; OE = orthodontic extrusion; BA = bone augmentation; KGA = keratinized gingival augmentation; MGJM = mucogingival junction movement; GA = gingival augmentation; R = recession; GTA = gingival thickness augmentation on the facial side; PDR = pocket depth reduction; BA/OE% = bone augmentation/amount of orthodontic movement ratio (efficacy); GA/OE% = gingival augmentation/amount of orthodontic movement ratio (efficacy); BA/GA% = bone augmentation/gingival margin ratio.

outcomes during OFE. In fact, the majority of available data are derived from case reports or case series, and to date, little research has been conducted on this approach.⁴¹

This preliminary clinical study describes the biological changes that take place during OFE.

Hard Tissue Changes

In line with previous research, new bone was formed in all treated sites.^{28,36,37} An important parameter that has not been thoroughly described in previous research is the effectiveness of orthodontic movement in creating bone.⁴¹ A direct relationship between tooth

movement and bone regeneration has not previously been described. None of the patients showed a 1:1 bone formation/vertical movement ratio; the average was about 70%, meaning that the vertical orthodontic tooth movement did not convert completely into new bone. The remaining 30% can be defined as "the loss of efficacy" of the technique and is probably a result of the tooth having to erupt out of the pocket before periodontal health is attained. The present research, however, showed greater bone formation with respect to orthodontic extrusion than animal studies.²⁸

There were no statistically significant differences in the amount of BA/OE% achieved in the four subgroups

Table 4 Mean (\pm Standard Deviations) Clinical Measurements by Defect Type

Measurement	Defect classification				
	I	II*	III	IV	V
OE	4 \pm 1	6	3.4 \pm 2.0	5.7 \pm 1.0	6.8 \pm 1.3
BA	2.6 \pm 0.5	4.9	1.5 \pm 0.5	4.2 \pm 1.1	4.5 \pm 1.3
KGA	2.4 \pm 0.4	3.2	1.9 \pm 1.8	1.6 \pm 1.2	1.9 \pm 1.3
MGJM	1.4 \pm 0.4	1.3	3.4 \pm 1.4	2.2 \pm 1.2	2.6 \pm 1.2
GA	3.4 \pm 0.6	4.5	2.1 \pm 1.2	3.7 \pm 1.4	4.4 \pm 1.9
R	0.5 \pm 0.4	1.5	7.2 \pm 1.5	1.2 \pm 0.8	2.6 \pm 1.3
GTA	0.9 \pm 0.2	0.8	0.6 \pm 0.3	0.7 \pm 0.4	0.6 \pm 0.5
PDT2	1 \pm 0	2	1.7 \pm 0.5	1.4 \pm 0.7	1.8 \pm 0.8
PDT1	2 \pm 0	5	4.2 \pm 1.3	3.1 \pm 0.7	3.6 \pm 1.5
PDR	1 \pm 0	3	2.5 \pm 0.8	1.7 \pm 0.8	1.8 \pm 1.1
BA/OE%	66 \pm 14.4	82	54.7 \pm 29.6	73.2 \pm 14.1	71.9 \pm 7.8
GA/OE%	75.7 \pm 7.8	75	54.8 \pm 18.0	63.7 \pm 16.7	69.3 \pm 26.2
BA/GA	82.7 \pm 30.8	109.3	99.7 \pm 52.1	121.7 \pm 33.2	125.6 \pm 69.4

*Only one defect was classified as type II.

SD = standard deviation; OE = orthodontic extrusion; BA = bone augmentation; KGA = keratinized gingiva augmentation; MGJM = mucogingival junction movement; GA = gingival augmentation; R = recession; GTA = gingival thickness augmentation on the facial side; PDR = pocket depth reduction; BA/OE% = bone augmentation/amount of orthodontic movement ratio (efficacy); GA/OE% = gingival augmentation/amount of orthodontic movement ratio (efficacy); BA/GA% = bone augmentation/gingival margin ratio.

(Table 4). In agreement with other research, the residual attachment level on the tooth was not a limitation to the amount of regenerated bone. Clinically, this means that it is possible to regenerate bone by erupting teeth that have lost more than 90% of the surrounding bone.^{36,37}

Soft Tissue Changes

As observed by other authors, gingival growth occurred along with the hard tissue changes.³²⁻⁴⁰ The gingival margin moved coronally in all cases. Some cases showed a 1:1 gingival formation/vertical movement ratio, but on average, GA/OE% was around 65%. Variability in gingival behavior was by far more relevant than in bone. Three different clinical scenarios have been observed. In the first one, the gingival migration was proportional to the orthodontic movement. These are cases in which the previous periodontal treatment had relocated the gingival margin at about the crestal bone level and a shallow pocket was present at the time of orthodontic therapy. This type of gingival response is in accordance with previous research conducted in animals and humans.^{28,30} In the second scenario, gingival overgrowth was observed. This was probably a result of a gingival hyperplastic reaction to bacterial and mechanical stimuli. In the last group, very little gingival growth was observed. This very interesting feature was a common finding in teeth with a discrepancy between crestal bone height and gingival margin. The measurements always revealed that, if a periodontal pocket was

still present, the coronal movement of the tooth was followed by bone only. As the pocket was erupted out and healed, the soft tissue margin also followed. Accordingly, Mantzikos and Shamus observed that "teeth that are erupted in the presence of soft tissue pocket depth have to move coronally for a considerable distance before the gingival margin follows."^{32,36}

A clinical feature that has not been highlighted in previous research is the behavior of the gingival margin on teeth adjacent to the extruded tooth. In all cases, gingival coronal growth occurred not only on the extruded tooth but also, to a lesser extent, on the teeth next to extrusion site (Fig 2h). This phenomenon was defined as the "blanket effect," because it resembles the movement of a blanket, which, when pulled up from two corners, moves not only at the corners but at the center as well, albeit to a lesser extent.

A clinical consequence of the aforementioned biologic principle is the increase in apparent gingival recession, which has been described previously. Similar behavior was also described by Kajiyama et al.³⁰ In agreement with previous research,^{28,30,32,36} the residual pocket depth decreased because at the beginning of extrusion the alveolar crest migrates coronally together with the tooth, while the gingival margin does not until the pocket is closed.

Together with the gingival margin, a coronal migration of the papillae was observed in all cases. Any attempt to gather exact measurements of papillae

growth failed because reference points, such as the contact point or the crestal margin of the adjacent teeth, were not stable during treatment.

Changes in the position of the MGJ were also observed. There are four possible clinical scenarios for the MGJ.

1. The MGJ does not move coronally but the gingival margin does, resulting in an increase of the band of KG. This happens when the MGJ is apical to the alveolar bone, which does not move during tooth extrusion.
2. The MGJ moves coronally together with the gingival margin, resulting in a coronal migration of the gingiva with no increase in the band of KG. This happens when the MGJ is attached to the root surface and there is no probing depth on the tooth.
3. Neither the MGJ nor the gingival margin move coronally, resulting in neither coronal migration of the gingiva nor an increase of the band of KG. This happens when the KG is not attached to the underlying root.
4. The MGJ moves coronally, while the gingival margin does not, resulting in a decrease of the band of KG until the pocket is completely erupted out.

KG showed a wide range of changes. As shown by other research,^{30,32,36} an increase in width was recorded in the majority of cases. A parameter that has not been thoroughly investigated in previous research is the thickness of the gingiva on the buccal side (biotype). In this sample, an increase in thickness was a consistent finding ("biotype conversion").⁴²

Extrusion and Follow-up

A slow orthodontic extrusion rate was applied because it appeared to be the most appropriate to preserve the integrity of the residual periodontal attachment. Zachrisson suggested the slow extrusion of teeth and stated that, in the absence of scientific data about the force system to be used, he attempted to use "interrupted continuous forces."^{38,40} Bone apposition occurs at a rate of 1 mm per month; therefore a 4- to 5-week rest period between activations appeared to be the most appropriate.

Light (15 to 50 g) continuous forces are generally recommended to extrude teeth.^{41,43} Therefore, 1 mm of extrusion per month, obtained by placing vertical steps on light wires, appears to be the most desirable and reproducible.

It has been claimed that a buccal root torque component may be applied concomitantly to increase the buccolingual bulk of alveolar bone.^{39,41} In contrast, it can be speculated that the key to success is to extrude the tooth along the long axis of the root. The goal is

to avoid traumatic impact of the root surface with the alveolar walls, which could potentially be detrimental to the integrity of the buccal bone plate.⁴⁴

The end of extrusion was followed by a 2-month period of stabilization to allow mineralization of the new trabeculae. The stabilization interval in this protocol is similar to what has been previously described by other authors.^{35,36,39,41} The rationale is that a slow extrusion rate requires a short stabilization period.

Follow-up data are being collected. No major changes were detected during the observation period, and no implant failures have occurred.

Advantages of OFE/OISD

Orthodontic guided regeneration is a nonsurgical means of regenerating tissue. The major advantage of this technique is the possibility to rebuild both the hard and soft tissues and insert an implant without ever raising a flap, which usually results in bone resorption.⁴⁴ Since it is known from previous research¹⁸ that immediate extraction and implant placement in thin-biotype patients may result in recession, the present authors decided to apply the OFE technique, even in cases with no initial bone loss on the hopeless tooth, to overbuild the site to compensate for postextraction remodeling.

It is important to highlight that most of the patients treated with OISD needed conventional orthodontic therapy to correct malocclusion and esthetics. Therefore, OISD may be proposed as an option for patients who need an orthodontic appliance for conventional treatment.

CONCLUSION

The present results demonstrated the following:

- Orthodontic implant site development is a valid procedure to generate new hard and soft tissues.
- Bone augmentation/orthodontic extrusion was about 70% (orthodontic efficacy to generate new bone) and gingival augmentation/orthodontic extrusion (orthodontic efficacy to generate new gingiva) was about 65%.
- A limited residual attachment level on the tooth to be extruded was not a limitation to the amount of regenerated bone.
- The only limitation to vertical augmentation was the interarch space.
- The implant survival rate was 96%.

Orthodontic implant site development might be a valuable treatment option to regenerate tissues for implant site development in patients in need of conventional orthodontic therapy.

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