

Efficacy of Two Site-Development Procedures for Implants in the Maxillary Esthetic Region: A Systematic Review

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Purpose: The purpose of this systematic review was to identify studies in which either orthodontic extrusion or bone grafting was used prior to single implant placement in the maxillary esthetic zone and to compare the biologic, functional, and esthetic outcomes of these two approaches. **Materials and Methods:** An electronic MEDLINE search was conducted by three independent reviewers to identify English-language articles, published in dental journals between January 1992 and August 2013, reporting on single-implant site development accomplished by orthodontic forced eruption of nonrestorable teeth or by bone grafting procedures. The search terms were categorized into four groups comprising a PICO (problem, intervention, comparison, outcome) question. Supplementary manual searches of published full-text articles and related reviews were also performed. **Results:** The initial database search produced 301 relevant titles. After careful examination and discussion, 32 studies were selected for inclusion. No study directly comparing the two implant site development methods was identified. The observation periods of the available studies were either short or not stated. **Conclusion:** There is a substantial lack of evidence to determine which method for implant site development is better. Definitive conclusions cannot be drawn, since no clinical trials have directly compared these two methods. All included studies reported separately on the two implant site-development methods and used different protocols. According to the literature reviewed, it seems that both methods of implant site development are effective and neither method is superior. Multicenter studies and randomized clinical trials should be performed to evaluate the efficacy of these two methods. INT J ORAL MAXILLOFAC IMPLANTS 2015;30:73–94. doi: 10.11607/jomi.3652

Key words: anterior maxilla, bone grafting, implant site development, orthodontic extrusion, single implant

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Implant therapy has proven to be a successful treatment modality for completely^{1–4} and partially edentulous patients,⁵ including patients missing a single tooth.⁶ Nowadays, to replace a tooth in the esthetic zone, in addition to the traditional therapeutic approaches, which include conventional fixed partial dentures and composite resin-bonded prostheses, single-tooth implants may be considered as well.^{7,8} However, osseointegration along with adequate masticatory function and phonetics cannot guarantee the success of this therapeutic approach, since the esthetic outcome in the anterior maxilla is equally important. Thus, implant placement in that region should be implemented with great caution, mainly because of the associated esthetic implications.^{9–13}

A major factor influencing the functional, biologic, and esthetic success of an implant restoration is the quantity of residual hard and soft tissues. It has been demonstrated that tooth loss results in continuous progressive bone resorption and remodeling of the edentulous areas.^{14–16} As a result, the bone at the

implant recipient site may be highly deficient horizontally and/or vertically.

Augmentation of deficient hard and soft tissues resulting from deformities caused by congenital malformations, trauma, root fracture, or localized periodontal disease is often required to make “restorative-driven implant placement” possible.^{17,18} Site-development procedures are essential for proper three-dimensional implant placement to achieve an esthetic outcome, which is characterized by a harmonious emergence profile of the implant restoration, in conjunction with the presence of well-developed papillae, gingival symmetry, and stable soft tissues.¹⁹

Several surgical techniques have been employed to develop implant sites. These include bone and soft tissue grafting,^{20–22} guided bone regeneration,^{23–25} distraction osteogenesis,^{26,27} and ridge splitting.²⁸ Although adequate bone substructure is a prerequisite for successful osseointegration, this factor by itself cannot ensure a good esthetic result and long-term peri-implant health. Thus, many surgical procedures have been employed to increase the thickness of the soft tissues and develop an ideal contour.^{29–36} Optimal soft tissue thickness is also essential to hide the restorative margins of the implant restoration. It has been advocated that implants in the anterior zone should be placed 2 to 3 mm below the cemento-enamel junction of the adjacent teeth to cover the color of a metal abutment and obviate its exposure in case of gingival recession.^{18,37–40}

In addition to bone and soft tissue grafting, Heithersay⁴¹ and Ingber⁴² described a nonsurgical approach for the development of implant sites. This method is based on osteophysiologic and orthodontic principles⁴³ and was used initially for the management of isolated non-restorable teeth.⁴⁴ The advantages of this technique include the correction of local infrabony defects, relocation of the gingival margin, and clinical lengthening of the crown.^{45,46} Moreover, orthodontic extrusion has been used for periodontally compromised teeth with no periapical lesions for three-dimensional preparation of the topography of the area before implant placement.^{47,48} Through slow orthodontic extrusion of nonrestorable teeth and their periodontal apparatus, augmentation of the hard and soft tissue contours of potential implant placement areas has been shown to occur. With slow extrusion, the tooth moves 1 to 2 mm per month. With the application of light and constant forces, all periodontal fibers remain intact, osteoid tissue is uniformly deposited, and the bone crest and its overlying soft tissues are altered.⁴⁹

Both surgical and nonsurgical methods have been employed in the past for implant site enhancement. However, the efficacy of these methods has not been thoroughly evaluated. Therefore, the decision of which approach to use is sometimes difficult, and often

personal preference takes precedence over scientific evidence. If clinicians wish to use both methods and present both options to their patients, bone grafting and orthodontic extrusion need to exhibit similar results.

The purpose of this systematic review, therefore, was to identify studies that examined either orthodontic extrusion or bone grafting prior to single implant placement in the maxillary esthetic zone and compare the biologic, functional, and esthetic outcomes of these two approaches.

MATERIALS AND METHODS

The focused PICO (*population, intervention, comparison, outcome*) question of the present systematic review was whether the biologic, esthetic, and functional outcomes of orthodontic preextraction treatment are similar to those obtained by hard and soft tissue grafting in patients needing a single implant in the anterior maxilla. It was the intent of the authors to determine whether the literature offers clear indications about when the orthodontic extrusion of a hopeless tooth is recommended prior to single implant placement and when, instead, outright extraction followed by replacement with an implant is indicated.

Search Strategy and Study Selection

An electronic MEDLINE search was conducted by three independent reviewers to identify English-language articles, published in dental journals between January 1992 and August 2013, and reporting on single implant site development accomplished by either orthodontic forced eruption of nonrestorable teeth or bone grafting procedures. The search terms were categorized into the four groups comprising the PICO question after the following limits were activated: human; clinical trial; meta-analysis; randomized controlled trial; review; case reports; clinical trial phases I, II, III, and IV; comparative study; controlled clinical study; multicenter study. The search strategy was assembled with a combination of Medical Subject Headings (MeSH terms) and free-text words, as shown in Fig 1.

Supplementary manual searches of published full-text articles and related reviews, selected from the electronic search, were also performed. Additionally, manual searches were conducted by all three reviewers in the following journals of articles published between January 1992 and August 2013: *Journal of Prosthetic Dentistry*, *Journal of Prosthodontics*, *International Journal of Prosthodontics*, *International Journal of Oral & Maxillofacial Implants*, *Journal of Oral Implantology*, *Implant Dentistry*, *Journal of Clinical Periodontology*, *Journal of Periodontology*, *Clinical Oral Implants Research*,

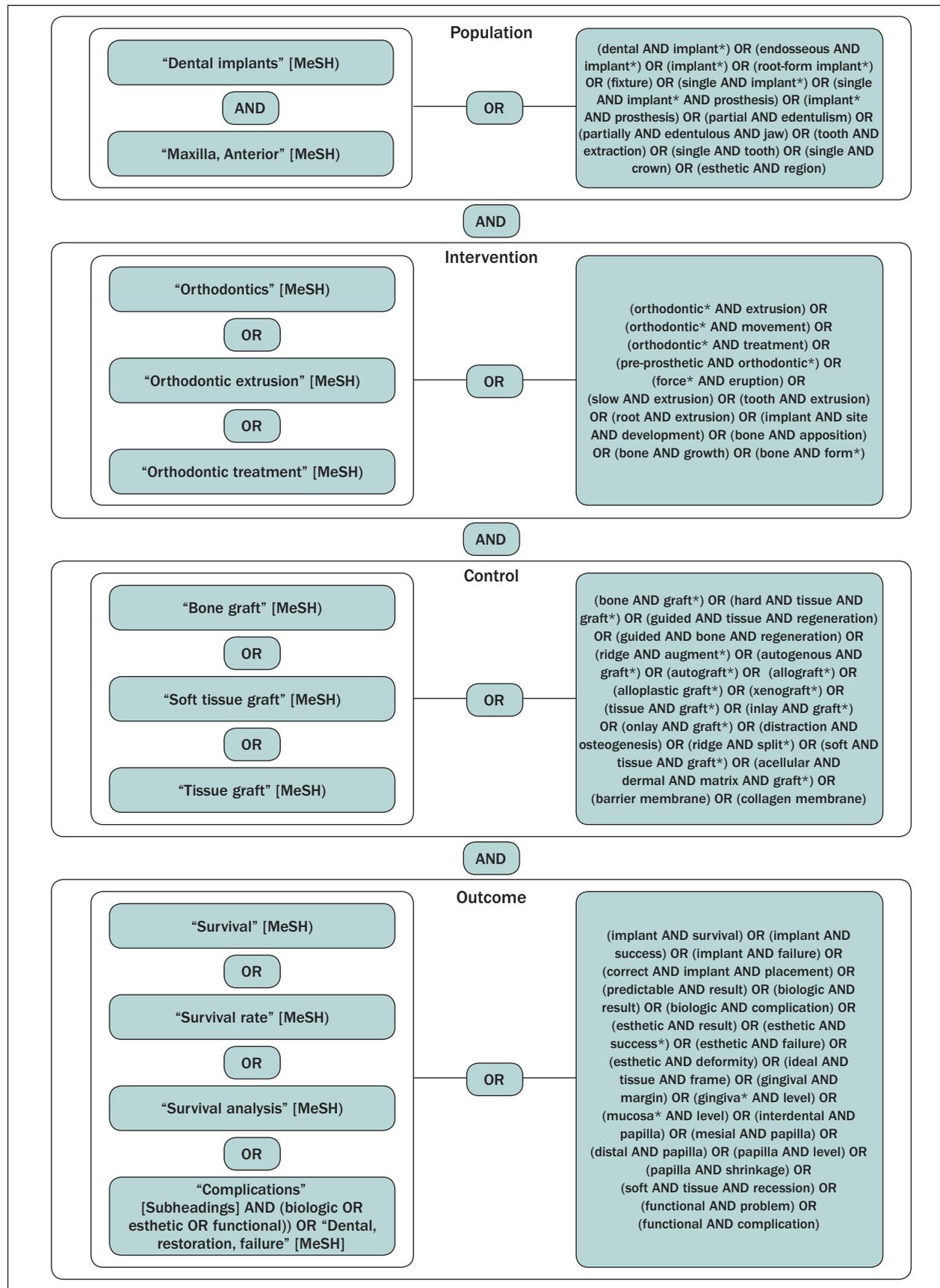


Fig 1 Use of the PICO questions to narrow the search.

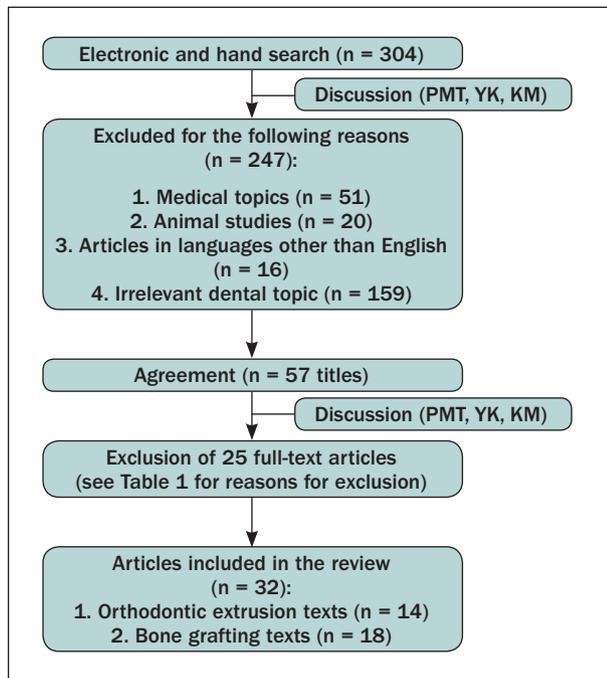


Fig 2 Flow chart of study selection.

Clinical Implant Dentistry and Related Research, Journal of Oral Rehabilitation, Angle Orthodontist, and International Journal of Periodontics & Restorative Dentistry.

This systematic review was based on case series and case reports retrieved through the electronic and manual searches described, since no randomized controlled trials or prospective or retrospective cohort studies could be found. The additional criteria for study inclusion were as follows.

- Report of one missing or failing tooth in the maxillary esthetic region, including the premolars, replaced by an implant after site development procedures
- Inclusion of detailed information on implant site development procedures
- Inclusion of a clinical evaluation of the result
- Report of the presence or absence of biologic, esthetic, and/or functional complications at follow-up

All studies that did not satisfy the aforementioned criteria (including in vitro studies, animal studies, reviews, systematic reviews, and clinical studies reporting on teeth in other locations) were excluded.

The titles and abstracts from the advanced search were initially screened by all three reviewers (PMT, YK, and KM) for possible inclusion in the review based on the set criteria. Any disagreement was resolved by discussion. After this, abstracts of all titles approved by the three investigators were downloaded and evaluated

individually. If the abstract met the inclusion criteria, the full text was obtained. Additionally, if insufficient information was included in either the title or the abstract, the full text was obtained in an effort to avoid excluding any relevant articles. After the collection of all full texts, the inclusion/exclusion criteria were used to identify the articles that would be used for the systematic review. All three reviewers agreed on the final selection of the articles.

Extraction of Data

Data regarding the following parameters were extracted: type of study; setting of study; patient age, sex, systemic disease, and smoking habits; tooth replaced by the implant; reason for extraction; bone defect; probing depth (PD) or recession; tissue biotype; treatment; immediate or late implant placement; implant dimensions and brand; type of surgery (ie, flap elevation or flapless); bone graft; restoration type; follow-up period; treatment outcome; soft tissue changes; hard tissue changes; complications; and implant survival rate.

RESULTS

A total of 57 articles were selected, from an initial yield of 304 studies. A second discussion among the reviewers took place for evaluation of these articles (Fig 2). Of the 55 full-text articles obtained and studied, 25 were excluded and were not analyzed further (Table 1).^{47,50-74} Fourteen studies reporting on orthodontic site development⁷⁵⁻⁸⁸ (Table 2) and 18 studies reporting on bone grafting for implant site development⁸⁹⁻¹⁰⁵ (Table 3) were included in the review.

Types and Settings of Studies

Thirteen case reports⁷⁵⁻⁸⁷ and one prospective clinical study⁸⁸ on implant site development by orthodontic extrusion were included in the review. Six case reports,^{93,94,96,97,101,102} eight case series,^{89-92,95,99,103,104} three prospective clinical studies,^{59,100,105} and one randomized controlled trial⁹⁸ on bone grafting procedures were also identified. Twenty-two patients were treated by forced orthodontic eruption, and 316 patients received bone grafting procedures for implant site development.

Unfortunately, no retrospective, prospective, or randomized controlled studies comparing these implant site development methods were available in the literature.

Six studies^{75,76,80,83,85,88} (42.85%) reporting on orthodontic extrusion did not include any information regarding the setting of the study, five^{77-79,81,84} (35.71%) were conducted in a private office, and three^{82,86,87}

Table 1 Studies Excluded from the Systematic Review

First author	Year	Study	Reason for exclusion
Salama and Salama ⁴⁷	1993	Case series	Multiple implants
Mantzikos and Shamus ⁶⁵	1997	Case series	Multiple implants
Mantzikos and Shamus ⁷⁰	1998	Case report	Multiple implants
Mantzikos and Shamus ⁶⁴	1999	Case series	Multiple implants
Smukler et al ⁶⁰	1999	Prospective randomized clinical trial	No clinical results are reported
Iasella et al ⁵⁵	2003	Prospective randomized clinical trial	Bone grafting procedures in posterior areas
McCarthy et al ⁶³	2003	Case series	Multiple implants, no details regarding the outcome
Nozawa et al ⁶⁸	2003	Case report	Posterior areas
Den Hartog et al ⁷³	2003	Prospective randomized clinical trial	Data extraction could not be performed
Kokich ⁵¹	2004	Review	Review
Cune et al ⁶⁶	2004	Case series	Alveolar cleft sites, multiple implants
Ostojic et al ⁶⁹	2005	Case report	Multiple implants
Erkut et al ⁶⁷	2007	Case report	Posterior areas
Meijndert et al ⁷⁴	2007	Prospective randomized clinical study	Same cohort with Meijndert et al ⁹⁸
Korayem et al ⁵³	2008	Systematic review	Systematic review
De Rouck et al ⁵⁶	2008	Prospective randomized clinical trial	Same cohort with Cosyn et al ⁵⁹
Holst et al ⁵⁰	2009	Review	Review
Brindis and Block ⁵²	2009	Review	Review
Thoma et al ⁵⁴	2009	Systematic review	Systematic review
Cosyn and de Rouck ⁵⁷	2009	Prospective randomized clinical trial	Same cohort with Cosyn et al ⁵⁹
Le and Woo ⁷²	2009	Case report	Alveolar cleft
Noelken et al ⁶²	2011	Case series	Multiple implants
Cosyn et al ⁵⁸	2012	Prospective randomized clinical trial	Same cohort with Cosyn et al ⁵⁹
Maiorana et al ⁷¹	2012	Case report	Multiple implants
Cheung et al ⁶¹	2013	Case series	Multiple implants

(21.42%) took place in a university setting. Eight studies^{89,91,94,96,100,101,105} (44.44%) reporting on grafting procedures did not include any information regarding the setting of the study, two^{90,103} (11.11%) were conducted in a private office, two^{93,104} (11.11%) were performed in a hospital, and six^{59,95,97-99,102} (33.33%) took place in a university setting.

Patient Demographics and Health Conditions

The age of the patients treated by orthodontic extrusion ranged from 18 to 62 years, while that of the patients who underwent grafting procedures ranged from 17 to 81 years. One case report⁷⁷ and one prospective clinical study⁸⁸ reporting on orthodontic extrusion did not include any data on the age of the patients. Similarly, one prospective study,¹⁰⁰ which included 40 patients who received bone grafts, did not give any information about the patients' ages.

Seventeen patients (77.27%) treated by orthodontic extrusion were women, while only four (18.18%) were men; one study did not report on patient sex (4.54%). The female/male ratio of patients treated by

grafting procedures was similar: 135 patients (42.72%) were women, 118 (37.34%) were men, and the sex of 63 patients (19.93%) was not reported.

Regarding the health of the patients treated with orthodontic extrusion, it was reported that 13 (59.09%) were healthy, whereas there was no information about the health conditions of the other 9 (40.90%) patients. Two hundred eight of the patients (65.82%) treated with grafting procedures were healthy, and only one patient (0.31%) was reported to have type 2 diabetes, mild hypertension, and mild kidney disease. There was no information provided about the medical history of the remaining 107 patients (33.86%) treated with bone grafts.

The information provided about the smoking habits of most of the patients (90.9%) treated with orthodontic extrusion was insufficient; two (9.09%) were reported as nonsmokers. Regarding the patients treated with grafting procedures, 126 (39.87%) of them were nonsmokers, 73 (23.10%) were smokers, and smoking information was not provided for the remaining 117 patients (37.02%).

Table 2 Orthodontic Implant Site Development

Study	Study type	Setting	Age (y)	Sex	Systemic disease?	Smoker	Tooth (FDI)	Reason for extraction	Defect	PD or R	Biotype	Treatment
Danesh-Meyer and Brice (2000) ⁷⁵	CR	NR	19	F	Healthy	No	11	Periodontitis	NR	PD 2–4 mm, R 7 mm	NR	Orthodontic extrusion for 8 wk, stabilization for 10 wk, extraction, implant placement, provisional 6 mo later, definitive metal-ceramic restoration 2 mo later
Zuccati and Bocchieri (2003) ⁷⁶	CR	NR	20	F	NR	NR	21	Periapical inflammation	Type II	NR	NR	Orthodontic extrusion for 4 mo, 2 mo passive retention, extraction, implant placement, correction of mucogingival defect 8 mo later, insertion of metal-ceramic restoration 2 mo later
Biggs and Beagle (2004) ⁷⁷	CR	PO	NR	NR	NR	NR	21	Periodontitis	Bone loss buccolingually and interproximally	NR	NR	Orthodontic intrusion and then extrusion, extraction, immediate implant placement, Hawley retainer as provisional, healing and definitive restoration
Chambrone and Chambrone (2005) ⁷⁸	CR	PO	48	M	Healthy	No	12	Fracture	Type II	PD 4.0 mm	NR	Orthodontic extrusion, stabilization for 10 wk, extraction, implant placement, definitive restoration 6 mo later
Gonzalez Lopez et al (2005) ⁷⁹	CR	PO	34	F	NR	NR	11	Periodontitis	Type V	R 6 mm	NR	Orthodontic extrusion for 4 wk, extraction, provisional fixed partial denture for 2 wk, implant placement, second surgery and healing abutment insertion, definitive all-ceramic crown
Park et al (2005) ⁸⁰	CR	NR	41	F	Healthy	NR	21	Periodontitis	NR	NR	NR	Forced eruption, stabilization for 6 wk, implant placement and immediate loading, definitive restoration 1 mo later
Lin et al (2006) ⁸¹	CR	PO	25	F	NR	NR	11	Periodontitis	NR	R Class III	NR	Orthodontic extrusion for 8 wk, implant placement, three-unit provisional
Holst et al (2007) ⁸²	CR	Univ	23	F	NR	NR	21	Non-restorable root	NR	NR	NR	Orthodontic extrusion for 4 wk, stabilization for 12 wk, extraction, implant placement, immediate loading, definitive restoration 6 mo later
Menini et al (2008) ⁸³	CR	NR	18	M	NR	NR	11	Ankylosed root	NR	NR	NR	Orthodontic extrusion, osteotomy of the maxilla and the ankylosed root, orthodontic distraction of the bone fragment, stabilization, extraction, implant placement, immediate loading, definitive restoration 5 mo later

Timing of implant placement	Implant	Placement approach	Bone graft*	Retention	Follow-up (mo)	Treatment outcome	Soft tissue changes	Hard tissue changes	Complications	ISR
Immediate	4.1 × 10 mm Straumann	Flap elevation	No	NR	NR	Successful esthetic result	NR	NR	Small tissue defect on the labial aspect	NR
8 wk post-tx	NR	Flapless	No	NR	24	Successful esthetic result; stable appearance	NR	NR	None	NR
Immediate	NR	NR	No	NR	NR	Successful esthetic result; stability	NR	NR	NR	NR
Immediate	3.75 × 11 mm, EH (Osseotite, Biomet 3i)	Flapless	No	Cement	NR	Successful biologic and esthetic result; satisfactory emergence profile	NR	NR	None	NR
Delayed (2 wk postextraction)	NR	Flap elevation	No	Cement	36	Stable periodontal tissues; satisfactory esthetic result	NEIP	NR	None	NR
Immediate	4.0 × 13 mm Nobel Biocare	Flapless	No	NR	24	Successful biologic and esthetic result	NR	NR	None	NR
Immediate	5.5 × 13 mm root-form (brand NR)	Flapless	No	Cement	24	Successful functional and esthetic restoration	Gain	NR	None	NR
Immediate	4 × 13 mm Replace, Nobel Biocare)	Flapless	No	Screw	18	Beneficial results; stable soft tissues	NR	NR	None	NR
Immediate	6 × 13 mm hybrid conical Osseotite, Biomet 3i	Flap elevation	No	Screw	12	Stable result	NR	NR	None	NR

Table 2 *continued* Orthodontic Implant Site Development

Study	Study type	Setting	Age (y)	Sex	Systemic disease?	Smoker	Tooth (FDI)	Reason for extraction	Defect	PD or R	Biotype	Treatment
Chandler and Rongey (2005) ⁸⁴	CR	PO	26	F	NR	NR	21	Periodontitis	Type II	PD 6.0 mm	NR	Root canal therapy, slow orthodontic extrusion (2 mm/mo), extraction, implant placement, definitive restoration
Uribe et al (2010) ⁸⁵	CR	NR	30	F	NR	NR	21	Periodontitis	NR	NR	NR	Periodontal therapy, orthodontic extrusion, endodontic therapy, intrusion of mandibular anterior segment, root fragment extraction, implant placement, acrylic provisional on a vacuum-formed retainer, definitive restoration 8 wk later
Kim et al (2011) ⁸⁶	CR	Univ	30	F	NR	NR	11	Periodontitis	NR	R Class IV	NR	Endodontic treatment, orthodontic extrusion of 11 and 12, stabilization, extraction of 11, implant placement 6 wk later, prosthetic restorations of teeth and implant
Amato et al (2012) ⁸⁸	Pr	NR	NR	2 M, 7 F	Healthy	Both	10 anterior teeth	NR	I, III, IV, V	NR	NR	Endodontic and periodontal therapy, orthodontic extrusion, stabilization for 2 mo, rapid extrusive force, flapless extraction and implant placement 2 days later, immediate loading, platform switching in some cases, definitive restorations 6 mo later
Makhmalbaf and Chee (2012) ⁸⁷	CR	Univ	62	F	N/C	NR	12, 22	Periodontitis	80% attachment loss	NR	NR	Root planing of the anterior maxillary teeth, orthodontic extrusion, pulpotomy of 22, extraction 7 mo later, immediate implant placement, provisionals 5 mo later, definitive restorations 7 mo later

CR = case report; EH = external hex; ISR = implant survival rate; N/C = not contributory; NEIP = not enough information provided; NR = not reported; PD = probing depth; PO = private office; Pr = prospective; R = recession; SD = standard deviation; Univ = university.
*To close the gap between the implant and the osseous walls.

Tooth- and Implant-Related Data

Only 14 teeth extruded orthodontically were identified with respect to location: 11 were central incisors (45.83%) and 3 were lateral incisors (12.5%). In the bone grafting group, the location of only 23% of treated teeth was reported: 32 (10%) were central incisors, 37 were lateral incisors (11.56%), 4 were canines (1.25%), and 1 was a second premolar (0.31%).

The most common reason for the extraction of teeth treated with orthodontic extrusion was severe periodontitis (41.65%). Other reported reasons included tooth fracture (4.16%), nonrestorable root (4.16%), and caries (4.16%). It should be pointed out that, in the prospective

study⁸⁸ included in this systematic review, no details were provided regarding the reasons for extractions (41.66%). The reason for extraction in those patients treated with bone grafting was reported in only 12.5% of the cases. Reasons included root fracture (4.37%), failure of endodontic treatment and caries (3.12%), periodontal disease (2.81%), root resorption (1.25%), periodontic-endodontic lesions (0.31%), and trauma (0.31%).

In the orthodontic extrusion group, information about the type of bone defect affecting the tooth that was extracted was provided for only five teeth: four (15.38%) had a type II defect, and one (3.84%) had a type V defect. In another study,⁸⁸ 10 teeth (38.46%)

Timing of implant placement	Implant	Placement approach	Bone graft*	Retention	Follow-up (mo)	Treatment outcome	Soft tissue changes	Hard tissue changes	Complications	ISR
6 wk post-tx	NR	Flapless	No	NR	NR	Satisfactory biologic and esthetic aspects	NR	NR	None	NR
Immediate	4.1 × 10 mm Straumann	Flapless	No	NR	NR	Satisfactory biologic and esthetic aspects	NR	NR	None	NR
6 wk post-tx	3.75 × 11 mm screw-type machined, Neodent	Flapless	No	Screw	60	Esthetic improvement; hard and soft tissue stability	NR	NR	Biologic (deficiency soft tissue)	NR
Immediate	3.25, 4, or 5 mm × 10, 11, 13, or 15 mm; all but one EH tapered (Biomet)	Flapless	Xenogeneic graft (Bio-Oss, Geistlich); only when a gap between the implant and the bone existed	Cement	18–61	Gingival augmentation, mean (SD) 3.9 (1.5) mm after mean orthodontic extrusion of 6.2 (1.4) mm	Mean (SD) + 1.8 (1.1) mm	Mean (SD) + 4 (1.4) mm	Recession ≤ 1 mm (five implants)	96.3%
Immediate	NR	NR	NR	NR	NR	Successful osseointegration; acceptable esthetics	Gain	Gain	None	NR

included all types of defects. Eleven of 18 articles (61.11%)^{59,89,91,92,94,96–99,102,105} included in the bone grafting group gave some information regarding the periodontal defect of the tooth that had to be extracted. Nevertheless, this information was inadequate to categorize the teeth into different defect types.

No information was given regarding PD and/or marginal tissue recession for 18 (75%) of the teeth included in the orthodontic extrusion group. One tooth (4.16%) presented with PDs of 2 to 4 mm, one (4.16%) had a PD of 4 mm, and one (4.16%) had a PD of 6 mm. The tooth with a PD of 2 to 4 mm also presented with marginal tissue recession of 7 mm. One study⁷⁹ gave

information only regarding recession of the involved tooth (4.16%), which was 6 mm, while two other studies^{91,96} utilized the Miller classification (III and IV, respectively) for the two teeth (8.32%) that were extracted after orthodontic extrusion.

No information was provided regarding PD or recession for 304 of the teeth (95%) included in the bone grafting procedure studies. For two teeth (0.62%), there was not enough information to draw a conclusion, while one tooth (0.31%) presented a 2-mm PD, one tooth (0.31%) presented an 8-mm PD, and one tooth (0.31%) presented a 13-mm PD. Eleven teeth (3.43%) presented a mean recession of 3.1 mm.

Table 3 Bone Grafting Implant Site–Development Procedures

Study	Study type	Setting	Age (y)	Sex	Systemic disease?	Smoker	Tooth (FDI)	Reason for extraction	Defect	PD or R	Biotype	Treatment
Leonetti and Koup (2003) ⁸⁹	CS (2 pt)	NR	52; 49	F	NR	NR	11;25	Fracture; NR	Loss of buccal plate; postextraction horizontal defect	NR	NR	Extraction, 6 wk healing, bone preparation, allogeneic graft preparation, placement of removable provisional, implant placement 6 mo later, definitive abutment and provisional crown 5 mo later, definitive metal-ceramic restoration 6 wk later
Steigmann and Wang (2006) ⁹⁰	CS (5 pt)	PO	Mean 40.2 ± 12 (range 28–55)	2 M, 3 F	Healthy	NR	Anterior teeth	NR	NR	NR	NR	Extraction, implant placement, GBR, immediate loading
Zeren (2006) ⁹¹	CS (3 pt)	NR	42; 53; 74	F, F, M	Healthy; healthy; type 2 diabetes, mild hypertension, mild kidney disease	NR	21; 22; 21	Fracture; fracture; fracture	> 60% of buccal plate (apical portion) was intact	NR	NR; NR; thick	Extraction, FDDB + EMD, absorbable barrier membrane prior to bone graft insertion (where needed), implant placement, abutment placement
Kan et al (2007) ⁹²	CS (23 pt)	NR	Mean 39.5 (range 25–63)	NR	NR	NR	Single anterior teeth (incisors and canines)	NR	Osseous defect categorized into V-, U-, or ultra-U-shaped	NR	Thick 10 pt, thin 13 pt	Provisional shell fabrication, extraction, implant and bone graft placement with a resorbable membrane, provisionals, definitive abutments and metal-ceramic restorations 6 mo later
Lai et al (2007) ⁹³	CR	Hosp	21	F	N/C	NR	12	NR	NR	NEIP	NR	Orthodontic treatment (right canine replaced the missing incisor and was recontoured to resemble lateral incisor), implant placement, ridge expansion and soft tissue augmentation, prosthetic restorations
Steigmann (2008) ⁹⁴	CR	NR	55	M	Healthy	NR	21	Periodontitis	Severe horizontal and vertical bone loss	PD 13 mm	NR	Extraction, BBM block + collagen membrane, implant placement 6 mo later, stage-two surgery 6 mo after implant placement, provisional 1 wk after, definitive restoration 3 mo later
Buser et al (2008) ⁹⁵	CS (45 pt)	Univ	Mean 39.9 (range 17–81)	29 M, 16 F	Healthy	32 no, 13 yes	Anterior	NR	NR	NR	NR	Extraction, 4–8 wk of soft tissue healing, implant placement + simultaneous facial contour augmentation (GBR) + bioabsorbable collagen membrane, autogeneic bone chips, provisionals, definitive metal-ceramic restorations

Timing of implant placement	Implant	Placement approach	Bone graft*	Retention	Follow-up (mo)	Treatment outcome	Soft tissue changes	Hard tissue changes	Complications	ISR
24 wk post-tx	3.7 × 13 mm screw-type implant; NR	Flap elevation	Allogeneic	Cement	12	Block graft integration; successful implant osseointegration	NR	NR	NR	NR
Immediate	NR	Flap elevation	NR	NR	12	Preserved soft tissue height; stable papillae	NR	NR	NR	NR
Immediate	NR; NR; 15 mm length	Flapless	Allogeneic	NR	24	Good anterior esthetic result	NR	NR	NR	NR
Immediate	Threaded tapered (Nobel Biocare) with planar (Replace Select) or scalloped (Nobel Perfect) platform	Flap elevation 15 pt, flapless 8 pt	Autogenous and allogeneic	Cement	12	Satisfying esthetic results	NR	NR	None	100%
Immediate	4.0 × 13 mm root-form	Flap elevation	NR	Screw	18	Acceptable esthetic result; functional success	NEIP	NR	None	NR
24 wk post-tx	3.7 × 13 mm tapered Screw-Vent, Zimmer	Flap elevation	Allogeneic	NR	24	Elimination of bone defect; good esthetic and biologic results	NEIP	< 1 mm	None	NR
4–8 wk post-tx	4.8 mm diameter; 12 standard, 33 tapered Straumann SLA	Flap elevation	Autogenous	Screw	24 (23 pt; 36 (16 pts); 48 (6 pt)	Successful facial contour; remodeling and esthetic result	+4–6 mm	NEIP	None	NR

Table 3 *continued* Bone Grafting Implant Site–Development Procedures

Study	Study type	Setting	Age (y)	Sex	Systemic disease?	Smoker	Tooth (FDI)	Reason for extraction	Defect	PD or R	Biotype	Treatment
Fagan et al (2008) ⁹⁶	CR	NR	52	M	NR	NR	21	Periodontal-endodontic lesion	15 mm vertical and 7–8 mm horizontal bone defect	NEIP	NR	Extraction, GBR with rhPDGF and FDBA, soft tissue augmentation with a PCTG and e-PTFE membrane, implant placement, cortical bone graft powder and BioGide to cover exposed implant threads, prosthetic restorations
Buser et al (2008) ⁹⁷	CR	Univ	23	F	Healthy	No	21	Dental trauma	Craterlike two-wall defect morphology on the facial aspect	PD 8 mm	Thin	Extraction, implant placement 8 wk later, bone graft w/cross-linked collagen membrane, provisional, definitive restoration 6 mo later
Meijndert et al (2008) ⁹⁸	RCT (93 pt)	Univ	Mean 33.3 ± 13.0 (range 18–63)	44 M, 49 F	Healthy	No	Anterior (incl premolars)	NR	Advanced horizontal bone deficiency	NR	NR	Extraction, graft (12 pt with autogenous bone) with Bio-Gide membrane or Bio-Oss spongiosa (24 pt) granules mixed with blood from the operative site, implant placement; stage-two surgery a few months later, definitive restoration
Buser et al (2009) ⁹⁹	CS (20 pt)	Univ	Mean 41.7 (range 24–60)	5 M, 15 F	Healthy	Yes	Maxillary anterior	NR	Craterlike bone defect	NR	NR	Extraction, 4–8 wk soft tissue healing, implant placement with simultaneous GBR, bone graft (granules), superficial layer of DBBM, non-cross-linked porcine-derived collagen membrane soaked in blood and applied in a double layer, provisionals, definitive all-ceramic restorations
Valentini et al (2010) ¹⁰⁰	PCS (40 pt, 43 impl)	NR	NR	NR	NR	NR	Anterior	NR	NR	NR	NR	Extractions, implant placement and bone substitute with collagen resorbable membrane (where needed), insertion of prosthetic abutment, provisional crown 1 wk later, definitive crown 3 mo later
Koutrach and Nimmo (2010) ¹⁰¹	CR	NR	48	F	NR	NR	11	Endodontic lesion and caries	NR	NR	NR	Tooth extraction and socket preservation with particulate cancellous BDB graft and a GTR membrane, 1 wk healing, removable provisional, implant placement 4 mo later, provisional crown, definitive crown 4 mo later

Timing of implant placement	Implant	Placement approach	Bone graft*	Retention	Follow-up (mo)	Treatment outcome	Soft tissue changes	Hard tissue changes	Complications	ISR
Immediate	4.0 × 13 mm Osseotite, Biomet/3i	Flap elevation	Allogeneic	NR	NR	Successful implant therapy; satisfying esthetic and biologic results	NR	NR	None	NR
NR	Straumann	Flap elevation	Autogenous and allogeneic	Cement	18	Healthy peri-implant soft tissues; stable bone crest levels; esthetic restoration	+4–6 mm	+3 mm	None	NR
12–24 wk	4.1-mm diameter Esthetic Plus, Straumann	Flap elevation	Autogenous and allogeneic	Cement	12	Satisfying esthetic results	+2.79 mm	–0.14 mm	2 implants lost (Bio-Oss pts); significantly deeper pockets around implants	97.8%
NR	4.1 × 10–12 mm Straumann SLA	Flap elevation	Autogenous	Cement, screw	24–48	Satisfying esthetic results	+4.5 mm	NEIP	NEIP	100%
Immediate	4.0, 4.5, or 5.0 × 11–13 mm Astra Tech ST	Flap elevation	Allogeneic	Cement	12	Predictable esthetic outcome; satisfying biologic results	NR	NR	2 implant failures	95.2%
16 wk post-tx	3.25 × 13 mm (calcium-phosphate-surfaced root-form implant)	Flapless	Xenogenic	Cement	12	Good esthetic and biologic result	NR	NR	NR	NR

Table 3 *continued* Bone Grafting Implant Site–Development Procedures

Study	Study type	Setting	Age (y)	Sex	Systemic disease?	Smoker	Tooth (FDI)	Reason for extraction	Defect	PD or R	Biotype	Treatment
Cosyn et al (2011) ⁵⁹	PCS (30 pt)	Univ	Mean 54 (range 24–76)	14 M, 16 F	Healthy	Smokers	Incisors, canines, premolars	NR	NR	NR	NR	Extraction, immediate implant placement, graft soaked in blood to fill the implant-alveolus void, provisional placed 3 h later, definitive restoration 6 mo after
Tekin et al (2011) ¹⁰²	CR	Univ	61	M	NR	NR	Left incisor	Periodontitis	Horizontal and vertical bone deficiency	NR	NR	Extraction, tissue healing, ridge augmentation using bone cylinder graft, simultaneous implant placement, stage-two surgery 4 mo later, definitive restoration 1 wk later
Furze et al (2012) ¹⁰³	CS (10 pt)	PO	Mean 45.1 ± 23.9	7 M, 3 F	Healthy	Smokers	Anterior	NR	NR	NR	NR	Extraction, implant placement with simultaneous GBR, immediate provisional, definitive restorations 2–3 mo later
Lee et al (2012) ¹⁰⁴	CS (10 pt)	Hosp	Mean 46.4	2 M, 8 F	NR	NR	Incisors (11 teeth)	NR	NR	R ≤ 5 mm (mean 3.1 ± 0.7 mm)	NR	Extraction, implant placement, graft to fill the gap, collagen membrane used when needed, connective tissue placed under mucoperiosteal flap, metal-ceramic restorations 4–6 mo later
Pieri et al (2013) ¹⁰⁵	PCS (29 pt)	NR	Mean 45.26 ± 11.83	18 F, 11 M	NR	NR	Incisors, canines	NR	≥ 3 mm horizontal and vertical bone loss	NR	NR	Block graft preparation and placement, provisional bonded fixed partial dentures, implant and connective tissue graft placement 6 mo later, implant-supported provisional 5–6 mo later, definitive Zr restorations 3–4 mo later

BBM = bovine bone mineral; BDB = bovine-derived bone; CR = case report; CS = case series; DBBM = demineralized bovine bone mineral; DPL = distal papilla level; EMD = enamel matrix derivative; e-PTFE = expanded polytetrafluoroethylene; FDBA = freeze-dried bone allografts; GBR = guided bone regeneration; GTR = guided tissue regeneration; Hosp = hospital; MPL = mesial papilla level; N/C = not contributory; NEIP = not enough information provided; NR = not reported; PCS = prospective clinical study; PCTG = porcine-derived connective tissue graft; PD = probing depth; PO = private office; R = recession; RCT = randomized controlled study; rhPDGF = recombinant human platelet-derived growth factor; Univ = university.

None of the cases treated with orthodontic extrusion reported the gingival biotype of the patients. Regarding the papers that reported on grafting procedures, only three studies^{91,92,97} gave information regarding the biotype of the patients treated: 14 patients (4.43%) presented a thin biotype, while 11 patients (3.48%) presented a thick biotype. Therefore, there is no information regarding gingival biotype for 291 patients (92%).

Treatment Protocols

In all studies, a stabilization period followed the orthodontic extrusion. More specifically, one study (7.14%) included a retention period that lasted 2 weeks, another (7.14%) 6 weeks, two studies (14.28%) 8 weeks, two more studies (14.28%) 10 weeks, and one study (7.14%) 12 weeks. Seven studies (50%) provided no information regarding the retention period.

Timing of implant placement	Implant	Placement approach	Bone graft*	Retention	Follow-up (mo)	Treatment outcome	Soft tissue changes	Hard tissue changes	Complications	ISR
Immediate	4.3 × 10 mm (2), 4.3 × 13 mm (8), 4.3 × 16 mm (14), 5 × 13 mm (2), 5 × 16 mm (4); all Nobel Biocare	Flap elevation	Xenogeneic (Bio-Oss, Geistlich)	Cement	≤ 12	Satisfying biologic and esthetic results	MPL -0.41 ± 0.71 mm, DPL -0.31 ± 0.83 mm; no significant changes in midfacial soft tissue levels (at all time intervals)	-0.98 mm (mesially), -0.78 mm (distally)	1 implant failure; 1 definitive crown lost retention (at 8 mo; re cemented)	97%
Immediate	3.7 × 16 mm, Implant Direct	Flap elevation	Autogenous	NR	12	Satisfying esthetic and biologic outcome	NR	NR	None	NR
6–8 wk post-tx	SLActive bone-level, Straumann	Flap elevation	NR	Cement	12	Satisfying esthetic and biologic result	NR	NR	Fracture of provisionals five times in three pt	NR
Immediate	AVANA USS1, Osstem	Flap elevation	Allogeneic	Screw	≤ 24	Stable rehabilitation, successful restorations	+2.1 mm since implant placement	NR	None	NR
24 wk post-tx	3.5 or 4 × 11, 13, or 15 mm (Astra Tech, OsseoSpeed; Xive, Dentsply)	Flap elevation	Autogenous and allogeneic (Bio-Oss, (80:20 ratio)	Cement	≤ 60	Stable rehabilitation, successful esthetic outcome	+0.13 ± 0.17 mm (mesial), +0.19 ± 0.37 mm (distal) since implant placement	+4.23 ± 0.69 mm (width), +1.71 ± 0.75 mm (height)	Biologic: 2 pt with early wound dehiscence, 1 pt with facial mucosa perforation over the grafted bone within 6 wk	100%

Three hundred twenty implants were included in the 18 papers reporting on bone grafting procedures. Immediate or early (1 week after implant surgery) loading was performed for 113 implants (35.31%) and delayed loading was performed for 207 implants (64.6%).

Implant placement was performed immediately after the extraction of most of the teeth (83.33%) treated with orthodontic extrusion, while four implants were placed

2 weeks (4.16%), 6 weeks (8.33%), or 8 weeks (4.16%) after extraction. In 114 cases (36.07%) of bone grafting procedures, implant placement was performed immediately, in 55 cases (17.4%) the implant was placed 4 to 8 weeks after extraction, and in 126 patients (39.87%) the implant surgery was performed 12 to 24 weeks after tooth extraction. For 21 patients (6.64%), insufficient information was provided on the timing of implant placement.

The brand of the implant in the orthodontic extrusion group was reported in 18 sites (75%), whereas no information was provided for the other six (25%). Information regarding implant dimensions was provided for 75% of the implants placed. Implant diameters ranged from 3.26 to 6 mm and lengths ranged from 10 to 15 mm. Likewise, the implant brand in the grafting studies was reported for 308 implants (96.25%), whereas no information was provided for the other 12 implants (3.75%). The diameter of the implants was reported in 83.43% of the cases and ranged between 3.25 and 5 mm, while the length was reported in 69.37% of the cases and ranged from 10 to 16 mm.

In most of the orthodontic extrusion cases (77.27%), implant placement was flapless. A flap was raised only in three sites (13.63%), while three remaining reports (13.63%) did not provide adequate information concerning the type of surgery. In almost all of the bone grafting cases (96.25%), the implants were placed after raising a flap; in only 12 cases (3.75%), implant placement was flapless.

A bone graft to fill the gap between the implant and the osseous walls was not used in any case treated with orthodontic extrusion. However, for some cases in one study,⁸⁸ no information was provided.

The graft types used in the grafting procedure studies included autogenous (16.66%), allogeneic (33.33%), xenogeneic (16.66%), and a combination of autogenous and allogeneic (22.22%). No information regarding the type of graft used was provided by 11.11% of the studies.

Thirteen (54.16%) of the restorations in orthodontic extrusion cases were cement-retained and only five (20.83%) were screw-retained. No information was provided for the restorations placed on six (25%) implants. Similarly, most of the implants (78.43%) placed in bone-grafted sites received cement-retained restorations, while 58 (18.12%) implant-supported restorations were screw-retained. No information on this subject was provided for 11 (3.43%) implants in the grafted sites.

Reported follow-up periods in cases treated with orthodontic extrusion were 12 months (4.54%), 18 to 61 months (68.18%), and not provided (six studies, 27.27%). Similarly, the follow-up times in cases treated with bone grafting procedures were 12 months (65%), 18 months (0.62%), 24 months (11.87%), 36 months (5%), 48 months (8.12%), and 60 months (9.06%). In only one case (0.31%) was no information provided about the follow-up period.

Treatment Outcomes

For both the orthodontic extrusion and the bone grafting cases, the outcomes were not analyzed statistically, since they were subjective.

A soft tissue gain was noticed in 13 (54.16%) of the orthodontic extrusion implant development sites. Insufficient or no information was provided for 11 (45.82%) sites. Regarding the soft tissue changes after bone grafting treatment, a gain was detected in 159 sites (49.60%), while loss was observed in 30 sites (9.37%). Not enough or no information was provided for 131 sites (40.9%).

In the orthodontic extrusion group, hard tissue gain was reported in 12 (50%) sites, while no information was provided for another 12 (50%) sites. In the bone grafting group, hard tissue gain was noted in 30 sites (9.37%), while minimal bone loss (< 1 mm) was observed in 124 sites (38.75%). It is important to mention that the hard tissue gain reported ranged between 3 and 4.23 mm. However, the papers did not specify whether this gain refers to bone height or bone width. Additionally, insufficient information was provided for 65 (20.31%) sites, while nothing was reported on this subject for 101 (31.56%) sites.

No complications were observed in 66.66% of the implants placed in the orthodontic extrusion cases, while some biologic complications were reported for seven implants (29.16%). For one (4.16%) implant, no information was provided. No complications were reported for 139 (43.43%) of the implants placed in bone grafted areas. The frequency of biologic complications was 29.37%, while for prosthetic complications it was 1.25%. Five (1.56%) implant failures were reported. Finally, no or little information was provided for 31 (9.68%) implants.

Concerning the survival rates for the orthodontically extruded implants, information was provided in only one (7.15%) study (survival rate: 96.3%); no survival rates were reported in the remaining 92.85% of studies.⁸⁸ Similarly, 12 studies (66.66%)^{59, 89–91, 93–97, 101, 103, 104} of the bone grafting group did not give any information on this subject. Five studies^{59, 92, 98, 99, 105} reporting on bone grafting procedures demonstrated survival rates ranging from 97% to 100%. One study¹⁰⁰ reported a survival rate of 95.2%.

Because of a lack of standardized comparable studies, no statistical analysis was performed.

DISCUSSION

The purpose of this article was to assess the biologic, functional, and esthetic outcomes of two different approaches to implant site development when a single tooth was replaced in the maxillary esthetic region. For this reason, a systematic search of the literature was conducted to identify high-level evidence. One retrospective clinical trial, 4 prospective studies, 8 case series, and 19 case reports were included. No

comparative studies, let alone randomized controlled trials comparing the two different approaches could be found. Therefore, it was not possible to draw definitive conclusions. Regarding orthodontic tooth extrusion for implant site development, all but one of the included papers,⁸⁸ which was a prospective clinical study, were case reports. Likewise, the majority of the papers reporting on grafting for site augmentation purposes were case reports or case series. Only one paper⁹⁸ was a randomized controlled trial; it reported on the outcomes of two different grafting materials.

The mean age of the patients who underwent orthodontic treatment was lower than that of the patients who were treated with grafting surgery for augmentation purposes. However, it is not known whether this was a result of the fact that many older patients are unwilling to “wear braces” or the clinicians’ treatment preferences. The expected time frame, the additional therapeutic procedures needed, and the associated costs as explained to the patients may have contributed to their decision of which treatment to select.

The presence of a systemic disease before implant placement has been discussed in the literature. A retrospective study¹⁰⁶ that investigated the correlation between systemic diseases and implant treatment found a global failure rate of 3.6% and concluded that osteoporosis and Crohn’s disease, along with smoking habits, are significantly associated with early implant failure. Furthermore, the same authors¹⁰⁷ have concluded that these factors are not associated with late implant loss. The literature suggests that the level of evidence regarding the association between systemic diseases and implant loss is low¹⁰⁸ and stronger evidence is needed, especially regarding patients who are receiving oral bisphosphonates and the potential risk for osteonecrosis of the jaw. On the other hand, before commencing implant therapy, the control of any systemic disease is still considered important.¹⁰⁹ Therefore, any systemic disease in the patients included in a study should be reported. Unfortunately, 10 of the 14 articles reporting on orthodontic extrusion did not supply any information on patients’ health status. A higher proportion (10 of 19) of the papers reporting on grafting for implant site development commented on health issues of the patients.

Two recent retrospective cohort studies^{110,111} identified smoking as a predictor for implant loss. Although there is a recognized correlation between smoking and implant complications, few authors included this parameter in the studies selected for the present review.

The biologic and functional result of implant treatment is very important, regardless of the implant’s position (maxilla or mandible). However, the esthetic outcome is of paramount importance in the anterior

maxilla, especially in patients with a high lip line, as mentioned earlier. This was the primary reason that the present systematic review focused on the esthetic region. Since many patients show more than the six anterior teeth when laughing, it was decided that the maxillary premolars should be included as well.^{112,113} The majority of the teeth treated with both approaches were central incisors, followed by lateral incisors, canines, and premolars. This finding is consistent with the fact that the most common reason for extraction of the affected tooth in orthodontic cases was aggressive localized periodontitis, which usually affects incisors and molars of patients who are otherwise healthy.^{114–116} In the bone grafting group, root fracture and periodontal disease were the most frequent reasons for which affected teeth were extracted. This is reasonable, since central incisors are the teeth most commonly affected by trauma and aggressive localized periodontitis, as already discussed. Because periodontal disease may result in different types and degrees of bone deformities, the use of a classification system would be extremely helpful. Only one article⁸⁸ included a classification table with the different types of osseous defects, based on the amount of residual attachment. Several other authors^{76,78,79,81,84,86} classified the defects of the treated teeth as well. Unfortunately, many studies did not include any information on this subject.

Although it has been suggested that there is an association between a patient’s gingival biotype and the tendency toward gingival recession after surgical procedures,^{117–119} none of the papers reporting on orthodontic extrusion included any information on this subject. Similarly, only three reports^{91,92,97} of bone grafting procedures included gingival biotype as a parameter.

All reviewed papers provided detailed information regarding the treatment procedures followed and the materials used. The rate of orthodontic extrusion differed between the selected papers. Treatment lasted between 4 and 16 weeks, while the stabilization period ranged between 0 and 10 weeks. It seems that the adopted technique is influenced by the bone height of the adjacent teeth, the periodontal and endodontic condition of the tooth, and the magnitude and direction of forces. No evidence has been identified regarding the minimum amount of bone support that a hopeless tooth should have before initiation of orthodontic extrusion. The stabilization period after tooth extrusion varied between 0 and 10 weeks. The literature supports the notion that a retention phase is needed for bone apposition to occur at the apical portion of the extruded tooth to prevent intrusion.¹²⁰ The parameters of the treatment methods of the papers reporting on bone grafting as an implant site-preparation procedure will be discussed later.

Regarding the timing of implant placement in relation to the extraction of the tooth, in most of the studies in both groups, immediate placement was performed. Whenever delayed implant placement was chosen, it occurred between 2 and 8 weeks after orthodontic extrusion and between 4 and 24 weeks after bone grafting. Whether immediate implant placement is a safe approach has not yet been determined. A recent systematic review¹²¹ demonstrated that the 2-year survival rate of immediately placed implants is 98.4%. Another study¹²² found that, although implants placed early, ie, 4 to 8 weeks after tooth extraction, showed higher mean survival rates (100% over 61.9 months) than immediately placed implants (96.16% over 51.6 months), the difference was not remarkable.

In the majority of the studies included in this systematic review, implants with a rough surface were used. An *in vivo* study¹²³ did not demonstrate a significant difference in survival rates after 12 months *in situ*. The authors found better behavior of rough-surface implants only when the quality of the surrounding bone was poor. However, there is evidence that implants with a rough surface give more predictable results in immediate loading cases.^{124–126} This finding is also supported by a clinical study in 25 patients¹²⁷ who received 78 machined Brånemark implants and 80 sandblasted/acid-etched Straumann implants in maxillary grafted areas. The authors concluded that, after 20 to 67 months of follow-up, the survival rate of the machined implants was 81%, while that of the rough implants was 98%.¹²⁷ The type of connection (external or internal) was not directly discussed in most of the included studies, with the exception of that of Amato et al,⁸⁸ who used mostly implants with an external-hex connection. However, since other authors reported the brand names of the implants (Nobel Replace, Astra Tech, and Straumann) it can be deduced that the majority of the inserted implants had an internal connection.

As seen from the results, there was a marked difference between the surgical approach (flap elevation vs flapless) in the two groups. While in the orthodontic extrusion group, flap elevation was reported in only three studies, in the bone grafting group, flap elevation was performed in all but three studies. This is probably a result of the methodology followed. When adequate bone volume is established with orthodontic extrusion, there is rarely a need for flap elevation. Conversely, there is often a need for flap elevation when implant placement is performed in combination with bone grafting procedures. A comparative study showed a difference in the outcome with the two approaches.¹²⁸

Bone grafting was not used in the cases treated with orthodontic extrusion, with the exception of some cases reported by Amato et al.⁸⁸ In those patients, a

xenogeneic graft (bovine bone material) was used whenever a small gap remained between the walls of the adjacent bone and the implant. A wide variety of materials were used in the studies reporting on bone grafting for implant site development. Autogenous bone (both chips and blocks), allogeneic grafts, xenogeneic grafts, or a combination of these, with or without barrier membranes, were employed. A radiographic follow-up study¹²⁹ of implants placed in particulate and block grafts harvested from the iliac crest and used as lateral onlays in 11 patients concluded that there were extensive volumetric changes after 6 months. Furthermore, after 2 years, particulate bone grafts displayed more resorption than the block grafts. Nevertheless, this difference was not statistically significant, and it did not have any effect on implants' osseointegration.

In the majority of the studies, cement-retained restorations were used. It has been discussed in the literature¹³⁰ that both types of restorations have limitations and advantages. Additional parameters that should be taken into consideration to ensure a successful esthetic result include the smile line, gingival biotype, characteristics of adjacent natural teeth, prosthetic materials of adjacent restorations, parafunctional habits, esthetic expectations of the patient, and possible financial limitations. The presence of a thin biotype in combination with a high smile line may necessitate the use of a zirconia abutment with an all-ceramic restoration.¹³¹

The follow-up time of the papers included in this systematic review varied greatly, from less than 12 months to 61 months. A very interesting point is that the duration of follow-up was not reported in seven studies, of which six were in the orthodontic extrusion treatment group. All of these studies were case reports. Therefore, it has to be assumed that the authors reported on the radiographic and clinical outcomes on the day of the delivery of the prosthetic restoration. This represents a common practice in published case reports, which probably should be altered, since the biologic and esthetic outcomes may change and technical complications may occur over time. This information is very important for clinicians to make definitive conclusions regarding the applied methods and materials. Follow-up of patients should be a prerequisite, and it constitutes one of the most important aspects of observational studies.¹³²

The vast majority of the studies included in this systematic review reported on biologic, functional, and esthetic outcomes in a rather descriptive manner. The only exceptions to that are one article⁸⁸ in the orthodontic extrusion group and three papers^{97,104,105} in the bone grafting group, which utilized objective criteria for both clinical and esthetic outcomes. Specifically, the Pink Esthetic Score,¹³³ which is used to objectively

assess soft tissues around single-tooth implants, was used in only two studies.^{95,105} The functional outcomes of implant restorations were discussed briefly in one study⁸¹ in the orthodontic treatment group and in one study⁹³ in the bone grafting group.

Although both orthodontic extrusion and the hard and soft tissue grafting were performed for development of the alveolar process, the majority of the studies did not report on the changes that resulted from these procedures. An assessment of the bone grafting papers that reported on this subject reveals that a soft tissue gain ranging between 1.12 and 6.00 mm occurred. The study of Pieri et al,¹⁰⁵ which reported thoroughly on this aspect, demonstrated soft tissue gain at the midfacial gingival margin but a mean loss at the mesial papilla of 0.13 mm and a mean loss at the distal papilla of 0.19 mm at the 5-year follow-up examination. Lee et al¹⁰⁴ demonstrated a mean soft tissue loss of 2.1 mm from baseline to the time of restoration insertion and a soft tissue gain of 0.3 mm at the 2-year examination. Unfortunately, only one paper⁸⁸ in the orthodontic extrusion group reported on this aspect and demonstrated a gain of 1.8 mm. A novel methodology for measurements of soft tissue changes was well described by Pieri et al.¹⁰⁵ It should be mentioned, however, that the baseline used for soft tissue changes was not the same for all studies. This has rendered it difficult to interpret the results and the efficacy of the methods and materials used.

The amount of hard tissue changes was not reported in the studies of orthodontic extrusion for implant site development, with the exception of one study.⁸⁸ Similarly, the majority of the papers included in the bone grafting group did not report on hard tissue changes. An exception to this is the research work of Amato et al⁸⁸ in the orthodontic extrusion group and the papers of Steigmann et al,⁹⁴ Buser et al,⁹⁵ Meijndert et al,⁹⁸ Buser et al,⁹⁹ Cosyn et al,⁵⁹ and Pieri et al¹⁰⁵ in the bone grafting group. Amato et al⁸⁸ reported a hard tissue gain of 4 mm, while the hard tissue changes in the bone grafting group ranged between -0.14 and 3 mm. The methodology used to measure hard tissue changes is not well described, with the exception of the work of Pieri et al,¹⁰⁵ who used computed tomographic scans before and 6 months after surgery. Marginal bone resorption was measured by the long-cone parallel technique utilizing custom-made film holders.

A few biologic and technical complications were reported. The biologic complications mainly include soft tissue deficiencies,^{75,86} recession,⁸⁸ deep pockets around implants,⁹⁸ wound dehiscence,¹⁰⁵ mucosal perforation,¹⁰⁵ and implant loss.^{59,98,100} Technical complications included frequent fractures of the provisional restoration in certain patients¹⁰³ and loss of retention of a definitive restoration.⁵⁹

An interesting finding of the present systematic review was that only two prospective studies^{59,100} and one randomized controlled trial⁹⁸ reported implant survival rates of 95.2%, 96.6%, and 97.8%, respectively. Therefore, it has to be assumed that the implant survival rate in the rest of the studies was 100%.

The main problem emerging from this systematic review is the absence of randomized controlled trials and multicenter studies comparing the two site implant development methods. In addition, the observation periods of the available studies are either not reported or rather short. Larger sample sizes, standardization of the procedures and data recording, in combination with detailed clinical and radiographic follow-up examinations, would be helpful in determining the advantages and disadvantages of each method, making better clinical judgments, understanding the limitations of each therapeutic method, and planning treatment accordingly.

CONCLUSIONS

The present systematic review demonstrated that there is a substantial lack of data and evidence to determine which of the two presented methods for implant site development is better. No definite conclusions can be drawn, since all included studies reported separately on the two implant-site development methods and used different protocols. As the reported data cannot be compared, no clinical recommendations can be made. According to the literature reviewed, it seems that both methods of implant-site development are effective. None of the presented methods is evidently advantageous over the other. Well-designed randomized clinical trials and multicenter studies should be performed to evaluate the efficacy of these two methods.

ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

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