

Clinical and Esthetic Outcomes of Implants Placed in Postextraction Sites

Stephen T. Chen, BDS, MSc, PhD¹/Daniel Buser, DMD, Prof Dr Med Dent²

Purpose: The aim of this review was to evaluate the clinical outcomes for the different time points of implant placement following tooth extraction. **Materials and Methods:** A PubMed search and a hand search of selected journals were performed to identify clinical studies published in English that reported on outcomes of implants in postextraction sites. Only studies that included 10 or more patients were accepted. For implant success/survival outcomes, only studies with a mean follow-up period of at least 12 months from the time of implant placement were included. The following outcomes were identified: (1) change in peri-implant defect dimension, (2) implant survival and success, and (3) esthetic outcomes. **Results and Conclusions:** Of 1,107 abstracts and 170 full-text articles considered, 91 studies met the inclusion criteria for this review. Bone augmentation procedures are effective in promoting bone fill and defect resolution at implants in postextraction sites, and are more successful with immediate (type 1) and early placement (type 2 and type 3) than with late placement (type 4). The majority of studies reported survival rates of over 95%. Similar survival rates were observed for immediate (type 1) and early (type 2) placement. Recession of the facial mucosal margin is common with immediate (type 1) placement. Risk indicators included a thin tissue biotype, a facial malposition of the implant, and a thin or damaged facial bone wall. Early implant placement (type 2 and type 3) is associated with a lower frequency of mucosal recession compared to immediate placement (type 1). *INT J ORAL MAXILLOFAC IMPLANTS* 2009;24(SUPPL):186–217

Key words: bone grafts, early implant placement, esthetics, immediate implant, implant survival

Advances in biomaterials and clinical techniques have facilitated significant expansion in the indications for dental implant therapy. In the beginning, the replacement of already missing teeth, eg, in edentulous patients, dominated daily practice. Today, many patients present for treatment to replace teeth that first need to be extracted before implants can be placed. This provides clinicians with the opportunity to decide on the timing of implant placement after tooth extraction.^{1,2} This decision is critical, since it has a significant influence on treatment outcome.² A recent systematic review of randomized controlled

trials (RCTs) identified only two studies of immediate implants that fulfilled the inclusion criteria.³ Although this review concluded that implants placed into fresh or healing sockets was a viable treatment option, more research was required.

The aim of this paper was to review the literature pertaining to implants placed in postextraction sites, and to identify the level of evidence and clinical outcomes for the different time points of implant placement following extraction.

MATERIALS AND METHODS

An electronic search of the dental literature using PubMed was undertaken to identify papers published in English between January 1990 and May 2008, using the following search terms: *dental implant, extraction, socket, immediate implant, immediate placement, delayed implant, delayed placement, and late placement*. A hand search of the following journals was undertaken: *Clinical Oral Implants Research, International Journal of Oral & Maxillofacial Implants, International Journal of Periodontics & Restorative Dentistry, Journal of Periodontology, Journal of Clinical Periodontology* and *Clinical Oral Implants*

¹Senior Fellow, Periodontics, School of Dental Science, University of Melbourne, Parkville, Victoria, Australia.

²Professor and Chairman, Department of Oral Surgery and Stomatology, School of Dental Medicine, University of Bern, Bern, Switzerland.

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Correspondence to: Dr Stephen Chen, 223 Whitehorse Road, Balwyn, VIC 3103, Australia. Fax: +61 3 9817 6122. Email: schen@balwynperio.com.au

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and Related Research. In addition, the reference lists of recent review papers were searched for additional citations.^{1,2,4-8} Papers accepted for publication were also included.

Selection of Studies

All clinical studies of implants in postextraction sites that included 10 or more treated patients were evaluated. For studies reporting on success and survival outcomes, only studies with a mean follow-up period of at least 12 months from the time of implant placement were included. Where a follow-up publication of a previous study was identified, the most recent study was included.

Studies were excluded if the mean follow-up period was not stated. In studies that reported on cases with different implant placement times after tooth extraction, studies were excluded if the data did not permit a differentiation of the placement time in subjects and sites.

Evaluation of Treatment Outcome

The following treatment outcomes were recorded:

- *Change in peri-implant defect dimension*, either as a reduction in defect area (mm² or %), defect height, width, and/or depth (mm or %), or as the change in the number of exposed implant threads. The following parameters were recorded: study design, implant surface, number of patients and implant sites, timing of implant placement after tooth extraction, implant sites, augmentation method, healing protocol (whether submerged or transmucosal), concomitant use of systemic antibiotics, healing time from implant placement to surgical reentry, and postoperative complications.
- *Implant survival*, recorded either as an overall survival rate or cumulative survival rate. Loading protocol and complications during the follow-up period were also recorded, in addition to the parameters listed above.
- *Esthetic outcomes*. The following parameters were recorded: descriptive soft tissue outcomes, esthetic indices, recession of the mucosa and papillae (in mm or % change), changes in probing depths or attachment levels, radiographic changes of the proximal bone, loading protocol, patient-evaluated esthetic outcomes, and complications during the follow-up period.

Definitions

In the literature, a number of descriptive terms have been used to describe when implants are placed after tooth extraction. The terms *immediate*, *recent*, *delayed*,

Table 1 Classification and Descriptive Terms for Timing of Implant Placement After Tooth Extraction (from Chen and Buser²)

| Classification | Descriptive terminology | Desired clinical outcome |
|----------------|--|---|
| Type 1 | Immediate placement | An extraction socket with no healing of bone or soft tissues |
| Type 2 | Early placement-with soft tissue healing (typically 4 to 8 wk of healing) | A postextraction site with healed soft tissues but without significant bone healing |
| Type 3 | Early placement-with partial bone healing (typically 12 to 16 wk of healing) | A postextraction site with healed soft tissues and with significant bone healing |
| Type 4 | Late placement (more than 6 mo of healing) | A fully healed socket |

and *mature* were introduced to describe the timing of placement in relation to soft tissue healing and the predictability of guided bone regeneration.⁹ The term *late* was used to describe time intervals of 6 months or more after extraction.¹⁰ More recently, the term *early* has been used to describe implant placement after initial soft and hard tissue healing but before complete healing of the socket has occurred.^{5,11,12}

The imprecise nature of these descriptive terms in the dental literature was discussed at the Third ITI Consensus Conference in 2003, and a new classification system for timing of implant placement after tooth extraction was proposed.¹³ A slight modification to the classification was made in a 2008 ITI publication, the ITI Treatment Guide, Vol 3 (Table 1).² This classification system was based on the desired clinical outcome of the wound-healing process, rather than on descriptive terms or rigid time frames following extraction. Type 1 placement refers to placement of an implant on the same day as tooth extraction and as part of the same surgical procedure. Type 2 placement occurs when the implant is placed after soft tissue healing, but before any clinically significant bone fill occurs within the socket. In contrast, type 3 placement is defined as placement of an implant following significant clinical and/or radiographic bone filling of the socket. In type 4 placement, the implant is placed into a fully healed site. This classification was validated in a recent review paper.¹ The authors of the paper felt that the classification was an appropriate means for describing the timing of implant placement in postextraction sites, as it accounted for variations in the healing capacity of individuals.

Although this classification system has clarified the terminology for implant placement in postextraction sites, various descriptive terms remain in wide use in the dental implant literature. Therefore, to

avoid ambiguity with respect to the timing of implant placement after extraction, the descriptive terms and classification adopted in the Third ITI Treatment Guide, Vol 3, were used simultaneously in this review.² The term *postextraction sites* was used to describe collectively fresh and healing extraction sites that permit implants to be placed immediately (type 1), early after soft tissue healing (type 2), and early after partial bone healing (type 3).

RESULTS

A total of 1,107 abstracts and 170 full-text articles were evaluated. Of these, 91 studies met the inclusion criteria for this review. Data were extracted from the studies and tabulated.

Regenerative Outcomes of Postextraction Implants

There were 28 studies reporting on healing of peri-implant defects in postextraction sites (Table 2). Eleven comparative studies were identified, of which 7 were RCTs.^{14–20} Four were prospective and retrospective studies.^{21–24} The remaining 17 studies were prospective and retrospective case series, the majority of which investigated immediate placement (type 1).^{25–38} Three studies reported on treatment outcomes with early placement (type 2).^{39–41}

How Effective Are Bone Augmentation Procedures? The majority of studies used combinations of bone grafts and/or barrier membranes to promote bone regeneration in peri-implant defects. The most commonly used augmentation material was deproteinized bovine bone mineral (DBBM), either alone^{31,33} or in conjunction with expanded polytetrafluoroethylene (e-PTFE) membranes¹⁵ or collagen membranes.^{21,22,24,30,32,40,41} Other augmentation materials included autogenous bone alone,^{17,26} e-PTFE barrier membrane alone,^{27,29} freeze-dried demineralized laminar cortical bone membrane,³⁴ composite graft of polymethyl methacrylate and calcium hydroxide,³⁶ and hydroxyapatite alone.¹⁶ Despite the heterogeneity of the evaluated bone-augmentation techniques and variations in methods for quantifying defect fill, all studies reported significant fill of the peri-implant defects, resulting in clinically acceptable resolution of the defects.

Five RCTs have provided data to compare different augmentation techniques (Table 3).^{14–16,19,20} In a study comparing defect height changes with immediate placement (type 1), defect reduction was significantly greater when an e-PTFE membrane was combined with demineralized freeze-dried bone allograft (DFDBA) than for an e-PTFE membrane alone after 6

months of submerged healing (5.68 ± 1.4 mm vs 3.18 ± 2.8 mm; $P < .04$).¹⁴ In a study of 83 patients comparing a hydroxyapatite graft and a resorbable polymer membrane with immediate placement (type 1) and submerged healing, no significant differences were observed in defect height resolution. Residual defect height for both groups was between 0.70 and 0.80 mm ($P = .772$).¹⁶ In a study comparing four different augmentation techniques (e-PTFE membrane alone, e-PTFE membrane and autogenous bone, resorbable polymer membrane and autogenous bone, and autogenous bone alone) with a nonaugmented control group, no significant differences were observed with respect to reduction in defect height and orofacial defect depth after 6 months of healing with immediate placement (type 1).¹⁹ However, sites treated with the addition of a membrane (e-PTFE or resorbable polymer) showed greater reduction in the mesiodistal width of the peri-implant defect. A study of immediate placement (type 1) with transmucosal healing reported no significant differences in defect height and depth reduction when comparing two augmentation methods (DBBM and collagen membrane, and DBBM alone) to a nonaugmented control group.²⁰

The results of these controlled clinical studies are supported by retrospective and prospective cases series studies with immediate (type 1) and early (type 2) implant placement. Without exception, these studies showed statistically and clinically significant resolution of the peri-implant defects. There is strong evidence to suggest that bone augmentation procedures are effective in promoting bone fill and defect resolution in peri-implant defects with both surgical approaches—immediate (type 1) and early (type 2) placement.

Are Bone Augmentation Procedures Necessary?

Recently, several studies reported on healing outcomes without the use of barrier membranes and bone grafts within the peri-implant defects in postextraction sites.^{19,20,23,35,37–39} In two separate studies, Chen et al reported that various combinations of barrier membranes and/or bone grafts and substitutes achieved similar defect resolution when compared to nonaugmented control sites that were allowed to heal with a blood clot alone.^{19,20} Defect height reductions between 68% and 83% were reported. Nir-Hadar et al reported that after 3 to 6 months of submerged healing, the residual vertical defect was less than 0.5 mm with early placement (type 2), irrespective of whether an initial orofacial defect was present or not.³⁹ Complete defect resolution was observed with immediate placement in a prospective study in 10 patients.³⁵ In this study, the peri-implant defects were less than 2 mm in the orofacial dimension. The same authors compared the outcomes of

Table 2 Clinical Studies Reporting on Healing of Peri-implant Defects Associated with Implants in Postextraction Sites

| Study | Study design | Implant surface | No. of patients (No. of implants) | Placement time after extraction | Augmentation method | Healing protocol | Defect changes |
|--|-----------------------|--------------------------------------|-----------------------------------|---------------------------------|--|------------------|---|
| Gelb (1993) ²⁵ | Prosp CS | Turned | 35 (50) | Type 1 | e-PTFE membrane, DFDBA graft or e-PTFE membrane + DFDBA graft | Submerged | 100% thread coverage for all techniques except in one case of a non-wall defect treated with DFDBA graft only, 76% coverage |
| Becker et al (1994) ²⁶ | Prosp CS | Turned | 30 (54) | Type 1 | Autogenous bone chips | Submerged | Mean initial defect height 5.5 ± 3.0 mm reduced to 0.5 ± 1.0 mm at reentry* Mean initial orofacial defect width 3.7 ± 2.1 mm reduced to 0.2 ± 0.8 mm* |
| Lang et al (1994) ²⁷ | Prosp CS | TPS | 16 (21) | Type 1 | e-PTFE membrane only | Transmucosal | 20/21 sites with complete bone regeneration |
| Becker et al (1994) ²⁸ | Multicenter Prosp CoS | Turned | 40 (49) | Type 1 | e-PTFE membrane only | Submerged | At sites with no early membrane removal (N = 29): mean initial defect height of 4.9 ± 2.5 mm reduced to 0.1 ± 0.4 mm at reentry† At sites with early membrane removal (N = 20): mean initial defect height of 6.4 ± 4.3 mm reduced to 2.4 ± 3.3 mm† |
| Nir-Hadar et al (1998) ³⁹ | Prosp CS | Turned | 14 (21) | Type 2 (6 to 8 weeks) | No augmentation | Submerged | Mean initial vertical defect 2.5 ± 0.37 mm reduced to 0.36 ± 0.64 mm when a horizontal (orofacial) defect was present* Mean initial vertical defect 3.86 ± 0.58 mm reduced to 0.48 ± 0.25 mm when a horizontal (orofacial) defect was absent* Mean initial horizontal (orofacial) defect 1.6 ± 1.73 mm reduced to 0.02 ± 0.02 mm* |
| Hämmerle et al (1998) ²⁹ | Prosp CS | TPS | 10 (11) | Type 1 | e-PTFE membrane only | Transmucosal | Mean initial vertical defect 4.7 ± 1.3 mm reduced to 2.1 ± 0.8 mm at reentry† 94% defect volume fill† |
| Nemcovsky et al (1999) ³⁰ | Prosp CS | TPS and HA | 29 (33) | Type 1 | DBBM only in small (size of defects not specified) defects DBBM and resorbable collagen membrane in dehiscence defects > 4 mm | Submerged | No membrane sites: Mean initial defect height 1.9 ± 1.16 mm reduced to 0.3 ± 0.46 mm at reentry† Membrane sites: Mean initial defect height 4.6 ± 1.18 mm reduced to 0.7 ± 0.7 mm at reentry† |
| Nemcovsky et al (2000) ³¹ | Prosp CS | SBE and TPS | 24 (26) | Type 1 | DBBM only; intact bone walls | Submerged | Mean initial defect height 2.6 ± 1.72 mm reduced to 0.6 ± 0.70 mm† |
| Nemcovsky et al (2000) ⁴⁰ | Prosp CS | SBE and TPS | 21 (28) | Type 2 (5 to 7 weeks) | DBBM and resorbable collagen membrane; dehiscence defects were all > 4 mm or had > 25% of the implant surface exposed | Submerged | For single implants: Mean initial defect height 6.7 ± 2.23 mm reduced to 0.6 ± 0.69 mm at reentry Mean initial defect area 23.7 ± 11.49 mm ² reduced to 0.7 ± 0.99 mm ² at reentry For adjacent implants: Mean initial defect height 6.4 ± 1.03 mm reduced to 0.8 ± 0.27 mm at reentry Mean initial defect area 20.67 ± 4.4 mm ² reduced to 0.6 ± 0.40 mm ² at reentry |
| Nemcovsky et al (2000) ³² | Prosp CS | Various (micro-textured, TPS and HA) | 61 (61) | Type 1 | DBBM and resorbable collagen membrane (membrane not used when all bone walls were intact) | Submerged | Vertical gain in bone between 1.5 and 3.6 mm |
| Van Steenberghe et al (2000) ³³ | Prosp CS | Turned | 15 (21) | Type 1 | DBBM with no membrane | Submerged | Mean initial defect height 3.8 ± 0.6 mm reduced to 1.1 ± 0.3 mm at reentry |

Table 2 continued Clinical Studies Reporting on Healing of Peri-implant Defects Associated with Implants in Postextraction Sites

| Study | Study design | Implant surface | No. of patients (No. of implants) | Placement time after extraction | Augmentation method | Healing protocol | Defect changes |
|---|--------------|-----------------|-----------------------------------|---------------------------------|--|-----------------------|---|
| Rosenquist and Ahmed (2000) ³⁴ | Prosp CS | Turned | 25 (34) | Type 1 | Freeze-dried demineralized human lamellar cortical bone used as a barrier membrane | Membrane left exposed | Mean initial defect height of 8.5 mm reduced to 0.3 mm at reentry |
| Hämmerle and Lang (2001) ⁴¹ | Prosp CS | TPS | 10 (10) | Type 2 (8 to 14 weeks) | DBBM and resorbable collagen membrane | Transmucosal | Mean initial vertical defect height reduced from 7.8 ± 1.9 mm to 2.5 ± 0.6 mm [†] Defect area reduction of 86 ± 33%; 8/10 sites had 100% defect area reduction |
| Covani et al (2003) ³⁵ | Prosp CS | SBE and TPS | 10 (15) | Type 1 | No augmentation; marginal defects between socket wall and implant were no more than 2 mm | Submerged | No residual bone defects observed; distance between facial and lingual bone walls reduced from 10.5 ± 1.5 mm to 6.8 ± 1.3 mm (35% change) |
| Yukna et al (2003) ³⁶ | Prosp CS | HA | 23 (30) | Type 1 | Composite of polymethyl methacrylate and calcium hydroxide | Submerged | Orofacial internal socket dimension reduced from 6.9 to 0 mm External ridge width decreased from 9.1 ± 2.4 mm to 8.4 ± 1.9 mm (<i>P</i> = .08) |
| Botticelli et al (2004) ³⁷ | Prosp CS | SLA | 18 (21) | Type 1 | No augmentation | Semisubmerged | Defect height reduction: mesial 1.6 ± 3.8 mm; facial 5.5 ± 2.3 mm; distal 0.4 ± 2.3 mm; lingual 3.5 ± 2.7 mm Defect width reduction: mesial 0.3 ± 0.8 mm; facial 1.5 ± 0.7 mm; distal 0.1 ± 0.8 mm; lingual 1.1 ± 0.8 mm |
| Covani et al (2007) ³⁸ | Prosp CS | TPS | 20 (20) | Type 1 | No augmentation | Submerged | Mean reduction in crestal bone height was 0.8 mm (0 mm in 38% of sites, > 0 to 1 mm in 47% of sites, > 1 to 2 mm in 15% of sites) |

Study design: Prosp = prospective; CoS = cohort study; CS = case series.
 Implant surface: turned = equivalent to machined surface; TPS = titanium plasma-sprayed; HA = hydroxyapatite-coated; SLA = surface sandblasted with large-grit and acid-etched;
 SBE = sandblasted and acid-etched.
 Placement time after extraction: Type 1 = immediate placement at the time of extraction; Type 2 = early placement after initial soft tissue healing; Type 3 = early placement after substantial bone healing; Type 4 = late placement after complete healing of the ridge.
 Augmentation method: e-PtFE = expanded polytetrafluoroethylene membrane; DBBM = demineralized bovine bone mineral; DFDBA = demineralized freeze-dried bone allograft.
[†]Significant within-group change from baseline (*P* < .05).
[‡]Significant within-group change from baseline (*P* < .01).

Table 3 Controlled Clinical Studies Comparing Different Augmentation Methods Used with Implants Placed into Postextraction Sites

| Study | Implant surface | Placement protocol/ healing protocol/ clinical indications | Study aim/ outcome variables | Experimental groups and augmentation methods | No. of patients | No. of implants | Reentry period following placement | Results |
|-------------------------------------|-----------------|---|--|--|---|---|--|---|
| | | | | | | | | |
| Gher et al (1994) ¹⁴ | TPS and HA | Type 1/Submerged/ Maxillary anterior and premolar sites; mandibular canine, premolar and molar sites | RCT/To compare two bone augmentation methods at two implant surfaces/Change in defect height and crestal bone levels | Group 1: TPS surface and e-PTFE membrane only Group 2: TPS surface and e-PTFE plus DFDBA Group 3: HA surface and e-PTFE membrane only Group 4: HA surface and e-PTFE plus DFDBA | Group 1 = 10 Group 2 = 10 Group 3 = 10 Group 4 = 10 | Group 1 = 11 Group 2 = 12 Group 3 = 10 Group 4 = 10 | 6 mo | No differences between implant surfaces Mean defect height reduction: Non-DFDBA grafted = 3.18 ± 2.83 mm; DFDBA grafted = 5.68 ± 3.45 mm ($P < .04$) Mean crestal bone loss from most coronal bone crest: Non-DFDBA grafted = 1.59 ± 1.66 mm; DFDBA grafted = 1.53 ± 1.38 (NS) Mean crestal bone loss from most apical part of crest: Non-DFDBA grafted = 0.11 ± 2.76 mm; DFDBA grafted = -1.39 ± 2.76 (ie, gain in crestal bone height) ($P < .02$) |
| Zitzmann et al (1997) ¹⁵ | Turned | Type 1, 2, 3, 4/Submerged/Maxillary and mandibular sites-all locations | RCT/To compare bone augmentation using a resorbable collagen membrane with a nonresorbable e-PTFE membrane in a split-mouth randomized study/Change in defect area | Each patient required at least two immediate implants; one site randomly received a resorbable collagen membrane and the other site a nonresorbable e-PTFE membrane (provided there was 14 mm of space between the two sites; if less than 14 mm the same membrane was used for both sites). DBBM was grafted at both sites | 25 | 84 Type 1 = 27 Type 2, 3, 4 (between 6 wk and 6 mo after tooth extraction) = 17 Healed site (more than 6 mo after extraction) = 40 | 4 mo in the mandible and 6 mo in the maxilla | Mean defect area reduction: e-PTFE membrane: 78 ± 50.2% Collagen membrane: 92 ± 19.3% ($P < .0001$) Mean defect area reduction in the presence of a wound dehiscence: For collagen membrane No dehiscence (n = 39): 94 ± 19.0%; Dehiscence (n = 4): 87 ± 18.9% (NS) For e-PTFE membrane No dehiscence (n = 23): 98 ± 9.8% Dehiscence (n = 18): 65 ± 68.4% ($P = .01$) |
| Prosper et al (2003) ¹⁶ | Sand-blasted | Type 1/ Submerged/ Maxillary and mandibular molar sites | RCT/To compare two bone augmentation methods in conjunction with a wide-diameter implant (5.9 mm)/Primary outcome variable-change in defect height | Group 1: HA graft only Group 2: Resorbable polymer membrane only | 83 patients total No. of patients in each group not stated; all patients belonged to the same treatment group/ Some patients received more than 1 implant | Group 1 = 56 Group 2 = 55 | 4 y from placement; all patients completed the 4-y follow-up | Residual vertical defect height: Group 1: range 0.70 to 0.80 mm Group 2: range 0.73 to 0.80 mm ($P = .772$) |

Table 3 continued Controlled Clinical Studies Comparing Different Augmentation Methods Used with Implants Placed into Postextraction Sites

| Study | Implant surface | Placement protocol/clinical indications | Study aim/outcome variables | Experimental augmentation methods | No. of patients | No. of implants | Reentry period following placement | Results |
|--------------------------------------|-----------------|---|--|--|--|--|------------------------------------|---|
| Cornelini et al (2004) ¹⁸ | SLA | Type 1/Transmucosal/Maxillary and mandibular canines and premolars | RCT/To compare the effect of demineralized bovine bone as an adjunct to resorbable collagen for bone augmentation at immediate implants | Test group: DBBM and resorbable collagen membrane Control group: Resorbable collagen membrane only | Test group = 10 Control group = 10 | Test group = 10 Control group = 10 | 6 mo | Mean radiographic crestal bone location from implant shoulder, baseline to 6 mo: Test group: 1.7 mm vs 1.8 mm Control group: 2.2 mm vs 2.1 mm Mean proximal mucosal margin levels coronal to the shoulder at 6 mo: Buccal Test group: 2.6 mm Control group: 2.3 mm ($P < .01$) Lingual Test group: 1.3 mm Control group: 1.1 mm ($P < .01$) Mean buccal mucosal margin levels coronal to the shoulder at 6 mo: Test group: 2.1 mm Control group: 0.9 mm ($P < .05$) |
| Chen et al (2005) ¹⁹ | Turned | Type 1/Submerged/Single-tooth implants in the maxillary anterior and premolar regions | RCT/To compare the effect of various bone augmentation procedures on healing of the peri-implant marginal defect/Primary outcome variables: defect height, width, and depth changes and resorption of the facial bone wall | Group 1: e-PTFE membrane only Group 2: Resorbable polymer membrane only Group 3: Resorbable polymer membrane and autogenous bone Group 4: Autogenous bone only Group 5: No augmentation; control | Group 1 = 12 Group 2 = 11 Group 3 = 12 Group 4 = 14 Group 5 = 12 Total = 62 | Group 1 = 12 Group 2 = 11 Group 3 = 12 Group 4 = 14 Group 5 = 12 Total = 62 | 2 y after loading | Defect height reduction (%): Group 1: 74.9 ± 27.8*; Group 2: 69.1 ± 27.6; Group 3: 83.1 ± 23.8; Group 4: 75.3 ± 20.9; Group 5: 73.6 ± 24.1 (NS) Defect depth (orofacial) reduction (%): Group 1: 73.6 ± 30.3; Group 2: 75.8 ± 34.3; Group 3: 89.7 ± 19.9; Group 4: 75.6 ± 26.0; Group 5: 69.7 ± 44.2 (NS) Defect width (mesiodistal) reduction (%): Group 1: 67.3 ± 23.6; Group 2: 60.6 ± 35.9; Group 3: 71.2 ± 29.2; Group 4: 34.1 ± 28.3; Group 5: 73.6 ± 24.1 ($P < .01$ between groups; Group 1 different from Groups 4 and 5, Group 2 different from Group 4, Group 3 different from Groups 4 and 5) |
| Chen et al (2007) ²⁰ | SLA | Type 1/Transmucosal/Single-tooth implants in maxillary anterior and premolar sites | RCT/To compare the effect of various bone augmentation procedures on healing of the peri-implant marginal defect/Primary outcome variables: change in defect height, width, and depth, and facial crestal bone | Maxillary anterior and premolar sites Group 1 (n = 10): DBBM Group 2 (n = 10): DBBM and resorbable collagen membrane Group 3 (n=10): No augmentation; control | Group 1 = 10 Group 2 = 10 Group 3 = 10 | Group 1 = 10 Group 2 = 10 Group 3 = 10 | 6 mo | Mean change in vertical defect height: Group 1: 81.2 ± 5.0%; Group 2: 70.5 ± 17.4%; Group 3: 68.2 ± 16.6% (NS) Mean change in defect depth (orofacial): Group 1: 71.7 ± 34.3%; Group 2: 81.7 ± 33.7%; Group 3: 55.0 ± 28.4% (NS) At sites with intact bone walls, mean change in facial crestal bone height: Group 1: 1.1 ± 1.2 mm; Group 2: 1.0 ± 0.6 mm; Group 3: 1.3 ± 0.9 mm (NS) At sites with intact bone walls, mean horizontal resorption of the facial bone: Group 1: 13.9 ± 16.7%; Group 2: 23.8 ± 23.4%; Group 3: 48.3 ± 9.5% ($P = .015$; Group 3 significantly greater than Groups 1 and 2) |

Implant surface: Turned = equivalent to machined surface; TPS = titanium plasma-sprayed; HA = hydroxyapatite-coated; SLA = surface sandblasted with large-grit and acid-etched. Placement protocol (placement time after extraction): Type 1 = immediate placement at the time of extraction; Type 2 = early placement after initial soft tissue healing; Type 3 = early placement after substantial bone healing; Type 4 = late placement after complete healing of the ridge. Study design: RCT = randomized controlled trial; CCS = controlled clinical study; CoS = cohort study; CS = case series. Augmentation method: e-PTFE = expanded polytetrafluoroethylene membrane; DBBM = demineralized bovine bone mineral; DFBDA = demineralized freeze-dried bone allograft; TCP = beta tricalcium phosphate.

*The authors reported standard error; standard deviation was derived from data presented in the paper.

type 1 and type 2 placement, and concluded that both approaches resulted in complete defect fill.²³ A human histologic study confirmed that spontaneous bone regeneration occurred in experimental peri-implant defects that were less than 2 mm in width, and that the newly regenerated bone became integrated with the previously exposed implant surface.⁴²

Covani and coworkers observed that complete defect fill occurred in the peri-implant gaps following type 1 and type 2 implant placement.^{23,35} The initial peri-implant gaps were 2 mm or less, and all sites had intact bone walls. These observations are corroborated by human histologic studies that have shown spontaneous bone regeneration and osseointegration when peri-implant defects were less than 2 mm in a horizontal dimension.⁴²⁻⁴⁴ In contrast, two studies examining healing outcomes when the initial peri-implant gaps were more than 2 mm reported that not all sites healed with complete bone fill. Botticelli et al demonstrated that 25% of sites with initial orofacial gaps of 2 to 3 mm healed completely, compared to 78% of sites with initial gaps of less than 2 mm.³⁷ Schropp et al observed that only 52% of sites with an initial orofacial defect depth of 4 to 5 mm healed spontaneously in the presence of intact bone walls.¹⁷

Summarizing these studies, there is evidence to show that peri-implant defects with gaps of less than 2 mm following type 1 and type 2 implant placement may heal with spontaneous bone regeneration and defect resolution. However, gaps of 2 mm or more in the orofacial dimension show clearly reduced predictability for spontaneous bone regeneration.

Do Implants Prevent Resorption of the Ridge in Postextraction Sites? Recent clinical and experimental studies have demonstrated that healing in postextraction sites is characterized by bone regeneration within the socket and external dimensional changes due to bone resorption and bone modeling.⁴⁵⁻⁴⁷ A series of well-designed experimental studies in a canine model have demonstrated that implants placed into extraction sockets of mandibular premolar teeth did not prevent these resorptive and modeling changes from taking place.^{48,49} The result is a reduction in the orofacial dimension of the ridge and a loss of crestal bone height, predominantly at the facial aspect of the ridge.

Several studies have provided clinical data on the dimensional changes that occur adjacent to implants in postextraction sockets when no augmentation was performed.^{35,37,38} In a prospective study, the distance between the facial and lingual bone walls changed from 10.5 ± 1.5 mm to 6.8 ± 1.3 mm (35% reduction in initial orofacial width) after 6 months of submerged healing.³⁵ In this study, implants were placed into extraction sockets (type 1 implant placement) in max-

illary and mandibular anterior and premolar sites. A further prospective study reported on type 1 placement of 21 implants in 18 patients.³⁷ Implant sites were confined to maxillary and mandibular anterior and premolar sites. After 4 months of submerged healing, the implant sites were reentered and changes in the dimensions of the ridges were recorded. External bone resorption and modeling resulted in a reduction in the orofacial crest width of 56% on the facial aspect and 30% on the lingual aspect. The height of the crestal bone was reduced by 0.2 to 0.6 mm. In a similar prospective study, Covani and coworkers reported a mean loss in facial crestal bone height of 0.8 mm after 6 months of submerged healing following type 1 placement in 20 patients.³⁸ Implant sites included maxillary and mandibular anterior and premolar sites. Although 38% of the sites showed no change, 47% had between 0 mm and 1 mm of loss, and 15% had between 1 and 2 mm of loss.

These studies provide strong evidence that type 1 placement per se does not prevent vertical or horizontal resorption of the ridges in postextraction sites.

Does Bone Augmentation Prevent Ridge Resorption with Postextraction Implants? Three RCTs^{14,19,20} and one prospective clinical case series³⁶ reported on the effect of bone augmentation on external dimensional changes with postextraction implant placement.

In a study of 40 patients, vertical resorption of the facial crestal bone was similar for sites treated with an e-PTFE membrane alone or an e-PTFE membrane and DFDBA (1.59 ± 1.7 mm vs 1.53 ± 1.4 mm) for type 1 placement after 6 months of submerged healing.¹⁴ Similar changes in facial crestal bone height were observed in a study of 30 patients who received 30 immediate implants and transmucosal healing.²⁰ After a healing time of 6 months, vertical resorption of the facial bone was 1.1 ± 1.2 mm for peri-implant defects grafted with DBBM, 1.0 ± 0.6 mm for sites augmented with DBBM and collagen membrane, and 1.3 ± 0.9 mm for nonaugmented control sites. There were no significant differences between groups. The results of these two studies are similar to results from studies of nongrafted postextraction implant sites with respect to vertical crestal bone resorption.^{37,38}

A study of various augmentation techniques with type 1 placement showed that although defect fill was similar, dehiscence defects showed significantly greater horizontal resorption than sites with intact bone walls.¹⁹ In another study by the same authors, significantly less horizontal resorption of the facial bone occurred when the peri-implant defects were grafted with DBBM (13.9% to 23.8%) compared to the nonaugmented control group (48.3%).²⁰ Similarly, Yukna and Castellon reported that following type 1 placement and grafting of the peri-implant defects

with a composite of polymethyl methacrylate and calcium hydroxide, the external dimensions of the sockets changed only slightly, from 9.1 ± 2.4 mm to 8.4 ± 1.9 mm (an 8% reduction in orofacial ridge width) after 6 months.³⁶ Both these studies used bone fillers with a low substitution rate.

These studies provide strong evidence that bone augmentation following type 1 placement reduces horizontal resorption of the facial bone. However, these augmentation procedures appear not to influence vertical resorption of the facial bone.

Does Damage to or Loss of the Facial Bone Affect Regenerative Outcomes? In postextraction sites, loss of one or more of the socket walls is a common observation. In a retrospective study of 75 patients, only 10 out of 31 extraction sites (32%) had intact bone walls.²¹ The majority of extraction sites presented with damage to the socket walls, with two-wall (52% of sites) or no-wall/one-wall (16% of sites) defects. The authors also reported that the proportion of two- and three-wall defects diminished as the time after tooth extraction increased. In an RCT, 60 out of 92 type 3 and type 4 implant placement sites had peri-implant defects. Of these, 48 were three-wall defects and 12 were dehiscence or two-wall defects.¹⁷

Several studies were identified that reported on treatment outcomes in postextraction sites in the presence of dehiscences of the socket walls.^{17,19,20,25,30,40} In two RCTs of type 1 placement using various augmentation techniques, sites with dehiscence defects achieved similar defect fill compared to intact sites.^{19,20} However, greater horizontal resorption of the facial bone occurred in the presence of a dehiscence, despite bone augmentation.¹⁹ In a prospective study of type 1 placement in 35 patients, 100% implant thread coverage was achieved in all sites except one site with a no-wall defect morphology, which achieved only 76% coverage.²⁵ In this study, DFDBA was used alone or in combination with an e-PTFE membrane. A study of type 1 implant placement in 29 patients receiving 33 implants showed significant gain in crestal bone height at dehiscence sites using DBBM and collagen membrane.³⁰ The resultant ridge height was similar to that observed in sites that initially had intact bone walls. In a study of type 2 implant placement in which all 28 implant sites in 21 patients presented with dehiscence defects, a defect area reduction of 97% was reported using DBBM and collagen membrane.⁴⁰ A gain in crestal bone height of 6 to 7 mm was recorded.

In contrast to these studies, Schropp et al reported that a trend toward greater bone fill was observed at sites with intact bone walls compared to sites with dehiscence defects.¹⁷

These studies provide strong evidence that bone augmentation following type 1 and type 2 placement

is effective in reconstructing the damaged facial bone. However, with type 1 placement, greater resorption of the facial bone was shown to occur in one RCT. This may have significant implications for esthetic outcomes. A recent study reported a high incidence of recession of the facial mucosa in the presence of defects of the facial bone with type 1 placement, despite bone augmentation using DBBM and collagen membranes.⁵⁰

Does Timing of Implant Placement Affect the Regenerative Outcome? There were six studies that provided comparative data on the effect of timing of implant placement on regenerative outcomes (Table 4).^{15,17,21-24}

Three studies compared immediate (type 1), early (type 2 or 3), and late (type 4) implant placement. In a split-mouth randomized study of dehiscence defects augmented with DBBM, Zitzmann et al reported less defect area reduction with healed sites (80% for e-PTFE membrane and 90% for collagen membrane) compared to immediate and healing sites (85% to 94% for e-PTFE membrane and 95% to 97% for collagen membrane) in 25 patients.¹⁵ Similarly, in a retrospective study of 75 patients by the same authors, defect area reduction was significantly better with type 1 and types 2 and 3 implant placement ($92\% \pm 20.8\%$ and $92\% \pm 20.7\%$, respectively) compared to type 4 ($80\% \pm 34.1\%$).²¹ The authors suggested that the difference was attributable to the greater proportion of one-wall/no-wall defects found with type 4 placement compared to immediate and early placements, which had a greater proportion of two-wall and three-wall defects. In another retrospective study, the use of DBBM and collagen membrane resulted in less defect area reduction with type 4 placement ($87.6\% \pm 11.5\%$) compared to type 1 ($90.2\% \pm 9.1\%$) and type 2 ($95.6\% \pm 8.7\%$) placement.²⁴ Type 2 placement achieved the best regenerative outcome in this study.

Two studies compared types 1 and 2 implant placement. In a prospective study using DBBM and collagen membrane to manage dehiscence defects, significantly greater defect area reduction was observed with type 2 placement ($91.2\% \pm 9.1\%$) compared to immediate placement (type 1; $77.4\% \pm 17.0\%$) in maxillary molar sites.²² Covani et al reported that both type 1 and type 2 placement in sites with intact bone walls achieved complete defect fill in the absence of simultaneous bone augmentation procedures.²³

One RCT compared early placement in 46 patients who received single-tooth implants in maxillary and mandibular anterior and premolar sites.¹⁷ Implants were placed a mean of 10 days after extraction (range 3 to 35 days) in the test sites (23 implants in 23 patients). In control sites (23 implants in 23 patients),

Table 4 Clinical Studies Comparing Different Times After Extraction and Their Effect on Healing of Peri-Implant Defects

| Study | Study design | Implant surface | No. of patients (No. of implants) by placement time after tooth extraction | | | | Augmentation method (healing protocol) | Observation period | Results for placement times after tooth extraction/method | | |
|--|--------------|------------------------|--|--|---|--|--|--|--|---|--|
| | | | Type 1 | Types 2 and 3 | Type 4 | Type 1 | | | Types 2 and 3 | Type 4 | |
| Zitzmann et al (1997) ¹⁵ | RCT | Turned | 25* (27) | 25* (17) | 25* (40) | DBBM and either non-resorbable e-PTFE or resorbable collagen membrane (randomly allocated) | 4 to 6 mo | Defect area reduction 85% for e-PTFE; 95% for collagen membrane | Defect area reduction 94% for e-PTFE; 97% for collagen membrane | Defect area reduction 80% for e-PTFE; 90% for collagen membrane | |
| Zitzmann et al (1999) ²¹ | Retro CS | Turned | 75* (31) | 75* (23) (placement time after extraction from 6 wk to 6 mo) | 75* (48) (placement time after extraction > 6 mo) | DBBM and resorbable collagen membrane (submerged) | 4 to 6 mo | Defect area reduction 92% ± 20.8% Defect morphology: no-wall/1-wall defect: 16% 2-wall defect: 52% 3-wall defect: 32% | Defect area reduction 92% ± 20.7% Defect morphology: no-wall/1-wall defect: 39% 2-wall defect: 55% 3-wall defect: 6% | Defect area reduction 80% ± 34.1% Defect morphology: no-wall/1-wall defect: 92% Trend toward less successful outcome of type 4 compared to types 2/3 and type 1 placements combined ($P = .05$) | |
| Nemcovsky and Artzi (2002) ²² | Retro CS | Microrough, HA and TPS | 19 (23) | 24 (31) (4 to 6 wk) | - | DBBM and resorbable collagen membrane (submerged) | 6 to 8 mo | Defect height reduction 77.4% ± 17.0% [§] Defect area reduction 90.2% ± 9.1% [§] (All sites presented initially with dehiscence defects) | Defect height reduction 91.2% ± 9.1% [§] Defect area reduction 97.2% ± 3.9% [§] (All sites presented initially with dehiscence defects) | - | |
| Covani et al (2004) ²³ | Prosp CS | NR | 33 (20) | 33 (20) (6 to 8 wk) | - | No augmentation (submerged) | 4 mo mandible, 6 mo maxilla | Facial to lingual ridge width change from 10.0 ± 1.5 mm to 8.1 ± 1.3 mm [†] Complete defect fill | Facial to lingual ridge width change from 8.9 ± 2.4 mm to 5.8 ± 1.3 mm [†] Complete defect fill | - | |
| Nemcovsky et al (2002) ²⁴ | Retro CS | HA and TPS | 19/23 | 25/39 (4 to 6 wk) | 22/40 | DBBM and resorbable collagen membrane (submerged) | 6 to 8 mo | Defect height reduction 77.4% ± 16.9% [§] Defect area reduction 90.2% ± 9.1% [§] | Defect height reduction 88.8% ± 15.3% [§] Defect area reduction 95.6% ± 8.7% [§] Significantly greater defect area and height reduction recorded for early placement (type 2) compared to the other 2 treatment groups | Defect height reduction 75.2% ± 18.0% [§] Defect area reduction 87.6% ± 11.5% [§] | |

Table 4 continued Clinical Studies Comparing Different Times After Extraction and Their Effect on Healing of Peri-Implant Defects

| Study | Study design | Implant surface | No. of patients (No. of implants) by placement time after tooth extraction | | | | Augmentation method (healing protocol) | Observation period | Results for placement times after tooth extraction | | | |
|------------------------------------|--------------|-----------------|--|--|--------|---|--|--------------------|--|--------|---|--|
| | | | Type 1 | Type 2 and 3 | Type 4 | Type 1 | | | Type 2 and 3 | Type 4 | | |
| Schropp et al (2003) ¹⁷ | RCT | Acid-etched | - | Group 1: 23 (23) early placement (mean 10 d; range 3 to 15 d after tooth extraction) | - | Autogenous bone in dehiscence sites (submerged) | 3 mo | - | Defect height reduction: Group 1: 48% Group 2: 34% (no significant differences between groups) Defect width (mesiodistal) reduction: Group 1: 48% Group 2: 39% (no significant differences between groups) Defect depth (orofacial) reduction (for sites with intact facial bone, ie, 3-wall defects only): Group 1: 59% Group 2: 77% (no significant differences between groups) | - | - | |

Study design: Retro = retrospective; Prosp = prospective; RCT = randomized controlled trial; CS = case series.

Implant surface: Turned = equivalent to machined surface; TPS = titanium plasma-sprayed; HA = hydroxyapatite-coated; SLA = surface sandblasted with large grit and acid-etched.

Placement time after extraction: Type 1 = immediate placement at the time of extraction; Type 2 = early placement after initial soft tissue healing; Type 3 = early placement after substantial bone healing;

Type 4 = late placement after complete healing of the ridge.

Augmentation method: e-PtFE = expanded polytetrafluoroethylene membrane; DBBM = demineralized bovine bone mineral; DFBBA = demineralized freeze-dried bone allograft; TCP = beta tricalcium phosphate.

- = Due to the study design, there were no data for this parameter.

* = not reported.

* Indicates total number of patients in the study.

† Significant within-group differences ($P < .05$).

‡ Significant within-group change from baseline ($P < .01$).

§ Significant between-group difference ($P < .05$).

implants were placed a mean of 14.1 weeks following extraction (range 9.3 to 19.7 weeks). Most sites did not receive bone grafts or membranes; three control sites received autogenous bone chips to cover dehiscences of the facial bone. The authors reported no statistically significant differences in defect height, width, and depth reduction between the two groups.

These studies provide strong evidence that augmentation procedures are more successful with immediate (type 1) and early (types 2 and 3) implant placement than with late placement (type 4). There is some evidence to show that regenerative outcomes are better with type 2 placement compared to type 1 placement in the presence of dehiscence defects of the bone. However, with intact bone walls, type 1 and type 2 placement achieve similar results with respect to fill of the peri-implant defect.

Does the Healing Protocol (Submerged Versus Transmucosal Healing) Affect Treatment Outcome?

Most studies used a submerged healing protocol following implant placement. In five studies that used a transmucosal healing protocol,^{18,20,27,29,41} the healing outcomes appeared to be similar to reports from studies using a submerged approach. No studies were identified that directly compared submerged with transmucosal healing for postextraction implants.

Evidence is lacking to demonstrate the superiority of one healing protocol over the other with respect to healing of peri-implant defects with postextraction implants.

What Are the Postoperative Complications with Postextraction Implants? The majority of studies with postextraction implants reported the occurrence of postoperative complications. Although not common, the most clinically significant complication with type 1 placement was postoperative infection or abscess formation leading to implant loss.^{19,51–56}

The most common complication reported was dehiscence of the wound and exposure of e-PTFE membranes when submerged healing was used with immediate implants.^{15,19,25,28,30,31,33–35,52,57–60} Three studies reported on the rate of complications with e-PTFE membranes,^{58,59,61} which ranged from 4.3% to 48% of sites. Studies with reentry defect data showed that this complication was associated with impaired healing and reduced bone fill in the peri-implant defects.^{15,28} Premature membrane exposure and infections in 15% to 20% of sites were reported in studies of type 1 placement using transmucosal healing when e-PTFE membranes were used.^{27,29} In studies using collagen membranes combined with bone grafts and bone substitutes, wound dehiscences were also reported.^{30–35,62,63} These studies reported complication rates ranging from 4.2% to 36.7%.

Since 1998, there has been a clear trend in study designs to use resorbable collagen membranes rather than e-PTFE membranes for bone augmentation. In the event of wound dehiscences, collagen membranes have been associated with less adverse healing outcomes. A split-mouth study which compared e-PTFE membranes with collagen membranes demonstrated that when wound dehiscences occurred, bone fill was significantly better in sites with collagen membranes than in sites with e-PTFE membranes.¹⁵ Furthermore, the healing outcomes were similar in sites with collagen membranes, whether or not a wound dehiscence occurred.

Other complications reported with type 1 placement included postoperative pain,^{38,52,64} sloughing of the flaps,^{30,31} postoperative bleeding,³¹ and temporary paresthesia.^{65,66} Absence of complications with type 1 implants was reported in only seven studies.^{26,38,67–71}

Only two studies reported on complications with type 2 placement. These included postoperative infection and necrosis of the flap in 2 out of 10 patients (20%)⁴¹ and postoperative bleeding.³¹ No complications were reported in two studies with type 2 placement and submerged healing.^{39,72}

Two studies provided comparative data on postoperative complications with postextraction implants placed with submerged healing. In a split-mouth study comparing type 1 and type 4 placement, premature implant exposure occurred in 7 out of 14 sites (50%) with type 1 placement compared to 4 out of 14 sites (28.8%) with type 4 placement. Bone augmentation with particulate hydroxyapatite was undertaken.⁷³ In a retrospective study in which autogenous bone chips were grafted into peri-implant defects, premature implant exposure occurred in 10.2% of sites with type 1 placement compared to 11.8% of sites with type 4 placement.⁷⁴

There were no studies that compared the rate of postoperative complications between type 1 and type 2 or 3 implant placements.

The evidence is clear that postoperative complications are common with immediate placement. The most common complication is dehiscence of the wound when either collagen or e-PTFE membranes are used in conjunction with submerged healing. There is strong evidence to show that in the presence of a wound dehiscence, collagen membranes result in better bone regeneration and defect fill compared to e-PTFE membranes. There were no comparative data for complication rates between type 1 and type 2 or 3 implant placements.

Do Systemic Antibiotics Enhance the Treatment Outcome?

The majority of studies included systemic antibiotics that were prescribed perioperatively and/or postoperatively. Amoxicillin was the most

commonly prescribed antibiotic. There were no studies that reported on the influence of systemic antibiotics on the outcome of bone augmentation procedures, or on the occurrence of postoperative complications.

Survival Outcomes of Postextraction Implants

A total of 54 papers reporting on survival outcomes of postextraction implants were identified (Table 5). There were 24 prospective and 11 retrospective studies; of these, the majority reported on survival outcomes with type 1 implant placement.^{25,27,50–52,54–56,58,59,61,63,64,67–71,75–85} Four studies provided data on type 2 placement.^{11,39,72,86}

There were 19 studies that provided data comparing different placement times after extraction (Table 6). Of these, only two were RCTs^{87,88} and two were controlled clinical studies.^{73,89} The remaining studies were prospective and retrospective case series studies.^{53,57,65,66,74,90–99}

What Are the Survival Outcomes of Postextraction Implants? The data on survival outcomes of postextraction implants were predominantly derived from studies with type 1 implant placement. Most studies (35 studies) were short term, with mean observation periods of 1 to 3 years. Survival rates ranged from 65% to 100% (median 99%), with 25 studies reporting survival rates of 95% or higher. Ten studies had mean follow-up periods of 3 to 5 years. Survival rates over this period ranged from 90% to 100% (median 95.5%). Only 3 studies were published with follow-up periods of greater than 5 years; survival rates for these studies ranged from 92% to 97% (median 95%).

Seven studies reported on survival after early implant placement (type 2), six of which were short-term studies of 1 to 3 years. One study provided comparative data between type 1 and type 2 placement over 4 years. The survival rates for type 2 placement ranged from 91% to 100% (median 100%).

There were only two studies that reported data on early implant placement with partial bone healing (type 3). The survival rates were 96% and 100%.

Due to the heterogeneity of the studies with respect to implant surfaces, loading protocols, and the relatively short-term observation period for the majority of studies, the data should be interpreted cautiously. However, it appears that survival rates for postextraction implants are high, with the majority of studies reporting survival rates of over 95%.

Does Timing of Implant Placement Influence Survival Outcomes? Of the 19 studies with comparative data, most compared type 1 and type 4 implant placement (11 studies). Three studies compared type 1 and type 2 implant placement. Two studies com-

pared type 2 and type 3 implant placement, and one study compared type 1 and type 3 implant placement (two of these studies were RCTs).^{87,88} One study had comparative data on type 1, type 2, and type 4 placement. The majority were short-term studies. Four studies reported follow-up periods of 3 to 5 years, whereas only one study had a follow-up time of over 5 years. In one retrospective study with comparative data, it was unclear when implants were placed after tooth extraction.⁹⁴

Type 1 Versus Type 4 Implant Placement. All studies comparing type 1 to type 4 implant placement were either retrospective or prospective cohort or case series studies. In seven studies with conventional or delayed loading, survival rates of type 1 implants ranged from 90% to 100% (median 99%) compared to 60% to 100% (median 94%) for implants with type 4 placement.^{64,73,90,91,96–98} In six studies of immediate restoration of single-tooth, short-span, and full-arch replacements, the survival rates of immediate implants (type 1 placement) was 65% to 100% (median 91%) compared to 94% to 100% (median 95%) for implants with type 4 placement.^{53,66,92,96,98,99} In one retrospective study providing data on three placement protocols, type 1 and type 2 implant placement had higher survival rates (99% and 100%, respectively) than type 4 implant placement (81.8%).⁵⁷

There is evidence to show that postextraction implants have survival rates similar to implants in healed sites. With immediate loading, type 1 implants may have lower survival rates than implants placed into healed sites.

Type 1 Versus Type 2 Implant Placement. Two short-term retrospective studies^{57,95} and one prospective cohort study with a 5-year follow-up⁶⁵ provided comparative data on type 1 and type 2 placement. Survival rates for type 1 implant placement ranged from 90% to 99% (median 90%) compared to a range of 90% to 100% (median 94%) for type 2 placement. Thus, implants placed with an immediate or early (type 2) protocol appear to have a similar survival outcome. In two studies, increased failure rates were noted in patients with a history of periodontitis.^{65,94}

Type 1 Versus Type 3 Implant Placement. Comparative data for type 1 and type 3 implant placement were examined in only one study, which was an RCT.⁸⁸ A total of 50 patients were selected, each with a single tooth site with radiographic evidence of chronic apical periodontitis. The patients were randomly allocated to receive either immediate placement or placement 12 weeks after extraction (type 3). A submerged healing protocol was used and patients were followed up for 12 months. The survival rates of implants placed immediately were 92% and 100% for type 1 and type 3 placement, respectively.

Table 5 Clinical Studies Reporting on Survival Outcomes with Postextraction Implants

| Study | Study design/ Placement time after tooth extraction | Implant surface | No. of patients (No. of implants) | Implant sites | Augmentation method/ Healing protocol | Loading protocol/ Restoration type | Observation period | Survival rate (%) |
|--|--|--------------------|--|--|---|--|-------------------------------------|----------------------|
| Gelb (1993) ²⁵ | Prosp CS/ Type 1 | Turned | 35 (50) | Maxillary and mandibular anterior teeth and premo- lars, and mandibular molars | e-PTFE membrane alone, or DFDBA graft alone, or e-PTFE membrane combined with DFDBA graft/ Submerged | Conventional/Single-tooth restorations | Mean 17 mo (range 8 to 44 mo) | 98 |
| Lang et al (1994) ²⁷ | Prosp CS/ Type 1 | TPS | 16 (21) | Maxillary incisors, canines, premolars, and mandibular premolars | e-PTFE membrane alone/ Transmucosal | Delayed/Single-tooth, short-span prostheses, short-span tooth-implant prostheses | Mean 30.3 mo (range 21 to 42 mo) | 100 |
| Rosenquist and Grenthe (1996) ⁵¹ | Retro CS/ Type 1 | Turned | 51 (109) | NR | No augmentation in most cases; e-PTFE membrane in 5 patients/ Submerged | Conventional in the mar- chile; delayed in the max- illa/Restoration type NR | Mean 30.5 mo (range 1 to 67 mo) | 93.6 |
| Pecora et al (1996) ⁵² | Retro CS/ Type 1 | TPS | 31 (32) | Maxillary and mandibular incisor, canine, premolar, and molar sites | e-PTFE membrane in 10 sites/ Submerged | NR/Single-tooth restora- tions | Mean 16.3 mo after loading | 96.9 |
| Cosci and Cosci (1997) ⁵⁸ | Retro CS/ Type 1 | HA | 353 (423) | NR | e-PTFE membrane for sites with intact bone walls; hydroxyapatite or DFDBA graft and collagen mem- brane for socket wall defects or apical fenestration/ Submerged | NR/Restoration type NR | Range 1 to 7 y | 99.5 |
| Schwartz-Arad and Chaushu (1997) ⁶² | Retro CS/ Type 1 | Turned and HA | 49 (85) | Maxillary and mandibular anterior, premolar, and molar sites | Autogenous bone chips/ Submerged | NR/Restoration type NR | Range 4 to 7 y | 95 after 5 y |
| Nir-Hadar et al (1998) ³⁹ | Prosp CS/ Type 2 (4 to 8 wk after extraction) | Turned | 14 (21) | All areas | No augmentation/ Submerged | Delayed/NR | 12 mo | 95.2 |
| Becker et al (1999) ^{59*} | Prosp multicen- ter CoS/Type 1 | Turned | 40 (49) | All areas | e-PTFE membrane alone/ Submerged | NP/Single-tooth replace- ments | 5 y | 93.9 |
| Grunder (2000) ⁸⁶ | Prosp CS/ Type 2 (8 wk after extraction) | Turned | 10 (10) | Maxillary central and lateral incisors | e-PTFE membrane and DBBM/ Submerged | Delayed/Single-tooth replacements | 1 y after loading | 100 |
| Schwartz-Arad et al (2000) ⁶³ | Retro CS/ Type 1 | Turned and HA | 43 (56) | Maxillary and mandibular molar sites only | Autogenous bone when required; e-PTFE (2 sites) and collagen mem- branes (6 sites)/Submerged | Delayed/Single-tooth and short spans | Mean 15 mo (range 4 to 60 mo) | 89.3 |
| Huys (2001) ⁶⁷ | Retro CS/ Type 1 | TPS | 147 (556) | NR | Composite polymer graft/ Submerged | Conventional/Ball- retained overdentures, short-span prostheses, implant-tooth prostheses, single crowns | Range 7 to 10 y | 96.6 |

Table 5 continued Clinical Studies Reporting on Survival Outcomes with Postextraction Implants

| Study | Study design/ Placement time after tooth extraction | Implant surface | No. of patients (No. of implants) | Implant sites | Augmentation method/ Healing protocol | Loading protocol/ Restoration type | Observation period | Survival rate (%) |
|--|--|-------------------------------------|--|--|---|--|----------------------------------|----------------------|
| Gomez-Roman et al (2001) ^{61†} | Prosp CS/ Type 1 | Grit blasted and acid- etched | 104 (124) | All sites | Autogenous bone (9 sites), HA (24 sites), e-PTFE membrane (17 sites)/Transmucosal | NR/Single-tooth, partial, and full arches | Mean 2.6 y (up to 6.3 y) | 97 |
| Goldstein et al (2002) ⁶⁸ | Prosp CS/ Type 1 | Turned | 38 (47) | Maxillary sites | DFDBA and resorbable polymer barrier membrane/Submerged | NR/Single-tooth replace- ments | Mean 39.4 mo (range 1 to 5 y) | 100 |
| Artzi et al (2003) ⁶⁹ | Prosp CS/ Type 1 | TCP blasted | 10 (12) | Maxillary molar sites only | DBBM or TCP/Submerged | NR/Single-tooth and extended spans | 2 y | 100 |
| Kan et al (2003) ⁷⁶ | Prosp CS/ Type 1 | HA | 35 (35) | Maxillary incisor and canine sites | No augmentation/Transmucosal | Immediate restoration/Sin- gle-tooth replacements | 1 y | 100 |
| Covani et al (2004) ⁵⁴ | Prosp CS/ Type 1 | TPS | 95 (164) | Maxillary and mandibular incisor, canine, and premolar sites | No augmentation at 58 sites with intact bone walls; autogenous bone chips and resorbable membranes in 105 sites with dehiscence and fenestration defects/Transmucosal | Immediate restoration/ Single-tooth replacements | 4 y | 97 |
| Bianchi and Sanfilippo (2004) ¹⁰⁶ | Retro CS/ Type 1 | TPS | 116 (116) | All sites | NR/Submerged | Delayed/Single-tooth replacements | 1 to 9 y | 100 |
| Cangini and Cornelini (2005) ⁷⁷ | Prosp CCS/ Type 1 | SLA | 32 (32) | Maxillary and mandibular incisor, canine, and premolar sites; all teeth had periodon- tal defects | Enamel matrix derivative (18 sites); resorbable collagen membrane (14 sites)/Transmucosal | Delayed/Single-tooth replacements | 12 mo | 100 |
| Cornelini et al (2005) ⁷⁰ | Prosp CS/ Type 1 | SLA | 22 (22) | Maxillary and mandibular incisor, canine, and premolar sites | Resorbable collagen membrane/ Transmucosal | Immediate restoration/ Single-tooth replacements | 12 mo | 100 |
| Vanden Bogaerde et al (2005) ⁵⁵ | Prosp CS/ Type 1 | Titanium oxide coated | 19 (50) | Maxillary anterior and pre- molar sites, and mandibular premolar and molar sites | Autogenous bone in 3-wall defects; autogenous bone and resorbable polymer membrane for 1- and 2- wall defects/Transmucosal | Immediate and early load- ing/Short-span to full-arch restorations | 18 mo | 100 |
| Barone et al (2006) ⁵⁶ | Prosp CS/ Type 1 | TPS | 18 (18) | Maxillary and mandibular incisor, canine, and premolar sites | No augmentation (all sites with intact bone walls and marginal gaps < 2 mm)/Transmucosal | Immediate restoration/ Single-tooth restorations | 12 mo | 94.5 |
| Ferrara et al (2006) ⁷⁸ | Prosp CS/ Type 1 | Grit-blasted/ acid-etched | 33 (33) | Maxillary and mandibular incisor, canine, and premolar sites | Ossseous coagulum if a marginal gap was present/Transmucosal | Immediate restoration/ Single-tooth restorations | 4 y | 94.0 |
| Fugazzotto (2006) ⁷⁹ | Prosp CS/ Type 1 | SLA | 83 (83) | Maxillary first and second molars | Ossseous coagulum or demineral- ized bone matrix paste with resorbable or titanium-reinforced e-PTFE membrane/Submerged | Delayed/Single restora- tions | Mean 12.4 mo in function | 100 |

Table 5 continued Clinical Studies Reporting on Survival Outcomes with Postextraction Implants

| Study | Study design/ Placement time after tooth extraction | Implant surface | No. of patients (No. of implants) | Implant sites | Augmentation method/ Healing protocol | Loading protocol/ Restoration type | Observation period | Survival rate (%) |
|--|--|--|--|---|--|---|--|----------------------|
| De Kok et al (2006) ⁸⁰ | Retro CS/ Type 1 | Titanium-oxide grit-blasted | 28 (43) | Maxillary anterior and premolar sites | NR/Transmucosal | Immediate restoration/ Single-tooth restorations | 12 to 30 mo (no mean) | 90.7 |
| Wagenberg and Froum (2006) ^{81,†} | Retro CS/ Type 1 | Turned and unspecified rough-surfaced implants | 591 (1,091) | Maxillary and mandibular incisor, canine, and premolar sites | Mineralized FDBA and resorbable polymer membrane/Submerged | Delayed/ Restoration type NR | 35% for 1 y 46% for 2 to 5 y 19% for 5 to 11 y | 95 |
| Covani et al (2007) ⁸² | Prosp CS/ Type 1 | Sandblasted and acid-etched | 10 (10) | Maxillary and mandibular incisor, canine, and premolar sites | NR/Submerged | Delayed/ Single restorations | 12 mo | 100 |
| Juozbalyas and Wang (2007) ⁸³ | Prosp CS/ Type 1 | NR | 12 (14) | Maxillary central and lateral incisors | DBBM and resorbable collagen membrane/Submerged | Delayed/ Single restorations | 12 mo after loading | 100 |
| Sammartino et al (2007) ⁷¹ | Retro CS/ Type 1 | SLA (53 implants) and grit-blasted/acid-etched (34 implants) | 55 (83) | Maxillary and mandibular incisor, canine, and premolar sites | No augmentation (all marginal gaps were ≤ 2 mm)/ Transmucosal | Early/Single- and multiple-tooth replacements | 2 y | 96.6 |
| Kan et al (2007) ⁵⁰ | Prosp CS/ Type 1 | Titanium oxide coated | 23 (23) | Maxillary central and lateral incisors, and canines | Autogenous bone or DBBM and resorbable collagen membrane/ Transmucosal | Immediate restoration/ Single-tooth restorations | 12 mo | 100 |
| Schwartz-Arad et al (2007) ⁶⁴ | Retro CS/ Type 1 | NR | 87 (210) | Maxillary and mandibular anterior teeth and premolars, and maxillary molars | DBBM and autogenous bone mixture/ Transmucosal | Immediate restoration/ Single-tooth and short-span restorations | Mean 15.6 \pm 12.6 mo (range 6 to 52 mo) | 97.6 |
| Crespi et al (2007) ¹²³ | Prosp CS/ Type 1 | TPS | 27 (150) | All sites | Autogenous bone chips/ Transmucosal | Immediate loading/ Full-arch maxillary and mandibular restorations | 18 mo | 100 |
| Villa and Rangert (2007) ⁸⁴ | Prosp CS/ Type 1 | Titanium oxide coated | 33 (100) | Maxillary incisors, canines, and premolars | Autogenous bone and DBBM/ Transmucosal | Immediate and early loading/Single-tooth, partial, and full-arch restorations | 12 mo | 97.4 ^{\$} |
| Caffiero et al (2008) ¹⁰⁰ | Prosp CoS/ Type 1 | SLA | 82 (82) | Maxillary and mandibular molars | DBBM and resorbable collagen membrane when marginal gaps > 1 mm/ Transmucosal | Early/Single-tooth restorations | 12 mo | 100 |
| Fugazzotto (2008) ⁶⁰ | Retro CS/ Type 1 | SLA | 386 (391) | Maxillary first and second molars | DBBM or demineralized bone putty, and titanium reinforced e-PTFE membrane/Submerged | NR/Single (387 implants) and splinted restorations (4 implants) | Mean 40.3 mo | 99.5 |
| Fugazzotto (2008) ¹⁰¹ | Retro CS/ Type 1 | SLA | 335 (341) | Mandibular first and second molars | DBBM or demineralized bone putty, and titanium reinforced e-PTFE membrane at sites with marginal gaps > 3 mm/Submerged | NR/Single-tooth and splinted restorations | Mean 30.8 mo | 99.1 |

Table 5 continued Clinical Studies Reporting on Survival Outcomes with Postextraction Implants

| Study | Study design/ Placement time after tooth extraction | Implant surface | No. of patients (No. of implants) | Implant sites | Augmentation method/ Healing protocol | Loading protocol/ Restoration type | Observation period | Survival rate (%) |
|--------------------------------------|--|--------------------|--|---|--|---|--|----------------------|
| Buser et al (2008) ¹¹ | Retro CS/ Type 2 (4 to 8 wk after extraction) | SLA | 45 (45) | Maxillary anterior and pre- molar teeth | DBBM and collagen membrane; graft applied to marginal defects and external surface of the facial bone/Submerged | Early/Single-tooth restora- tions | 23 patients for 2 y 16 patients for 3 y 6 patients for 4 y | 100 |
| Barone et al (2008) ⁸⁵ | Prosp CS/ Type 1 | TPS | 12 (12) | Maxillary premolar sites; all sites required simultaneous sinus floor elevation using osteotomes | Cortico-cancellous porcine bone and collagen gel, and resorbable membrane/Transmucosal | Delayed/Single-tooth restorations and multiple implant prostheses | 18 mo | 91.7 |
| Buser et al (2009) ⁷² | Prosp CS / Type 2 (4 to 8 wk after extraction) | SLA | 20 (20) | Maxillary anterior and pre- molar teeth | DBBM and collagen membrane; graft applied to marginal defects and external surface of the facial bone/Submerged | Early/Single-tooth restora- tions | 12 mo | 100 |

Study design: Prosp = prospective; Retro = retrospective; RCT = randomized controlled trial; CCS = controlled clinical study; CoS = cohort study; CS = case series.

Implant surface: Turned = equivalent to machined surface; TPS = titanium plasma-sprayed; HA = hydroxyapatite-coated; SLA = surface sandblasted with large-grit and acid-etched.

Placement time after extraction: Type 1 = immediate implant placement; Type 2 = early implant placement with soft tissue healing; Type 3 = early implant placement with partial bone healing;

Type 4 = late placement in a fully healed site.

Augmentation method: e-PTFE = expanded polytetrafluoroethylene membrane; DBBM = demineralized bovine bone mineral; DFDBA = demineralized freeze-dried bone allograft;

FDDBA = freeze-dried bone allograft; TCP = beta tricalcium phosphate.

Loading protocol: according to the ITI Consensus Conference (2003).¹²⁴ NR = not reported.

* This study represents the 5-year follow-up; 1-year results were published in Becker et al (1994).²⁸

[†]This study includes data from a previous report by the same authors: Wagenberg and Ginsberg (2001).¹²⁶

[§]Survival rate is for a subset of 76 out of 100 implants in 33 patients, that were placed in infected extraction sockets.

Table 6 Clinical Studies with Comparative Data on Survival Outcomes with Different Implant Placement Times After Extraction

| Study | Study design | Implant surface | No. of patients (No. of implants) | | | Augmentation method (healing protocol) | Loading/restoration type | Observation period | Survival rate (%) | |
|---|--------------|---------------------------------|-----------------------------------|---|-----------|--|--|---|-------------------|--------|
| | | | Type 1 | Type 2 and 3 | Type 4 | | | | Type 1 and 3 | Type 4 |
| Yukna (1991) ⁷³ | Prosp CCS | HA | 14 (14) | - | 14 (14) | HA/Submerged | Delayed/Splinted bridges | Mean 16 mo (range 8 to 24 mo) | 100 | 100 |
| Cranin et al (1993) ⁹⁰ | Prosp CCS | Polycrystalline Alumina Ceramic | 30* (25) | - | 30* (5) | No augmentation/Transmucosal | Delayed/Restoration type NR | Mean 85 mo (range not stated) | 92.0 | 60.0 |
| Watzek et al (1995) ⁹⁷ | Retro CS | HA and turned | 20* (97) | 20* (26) (6 to 8 wk after extraction) | 20* (11) | e-PTFE membrane with DBBM or hydroxyapatite grafts/Submerged | Delayed in the maxilla; conventional in the mandible/ Full-arch fixed restorations | Mean 27.1 mo (range 4 to 83 mo) | 98.9 | 100 |
| Polizzi et al (2000) ^{65†} | Prosp CoS | Turned | 143* (146) | 143* (34) (3 to 5 wk after extraction) | - | Combinations of e-PTFE and collagen membranes, autogenous bone and DFDBA/Submerged | Delayed in the maxilla; Conventional in the mandible/ Single-tooth, partial and full-arch restorations | 60 mo after functional loading | 90.4 | 93.6 |
| Schwartz-Arad et al (2000) ⁷⁴ | Retro | Turned and HA | 43* (117) | - | 43* (263) | Autogenous bone/ Submerged | Conventional loading in the mandible; delayed in the maxilla/ Full-arch restorations | 5 y | 96 | 89.4 |
| Jo et al (2001) ⁹¹ | Retro CS | NR | 75* (81) | - | 75* (205) | No augmentation/ Transmucosal | Immediate and delayed loading protocols used/ Restoration type NR | Mean 40 mo | 98.9 | 93.9 |
| Chaushu et al (2001) ⁵³ | Retro | HA | 20* (19) | - | 20* (9) | Autogenous bone/ Transmucosal | Immediate restoration/ Single-tooth restorations; sites NR | Mean 13 mo (range 6 to 24 mo) | 82.4 | 100 |
| Malo et al (2003) ⁶⁶ | Prosp CS | Turned | 76* (22) | - | 76* (94) | NR/Transmucosal | Immediate restoration in 73 patients/Single-tooth and short spans | 1 y | 100 | 94.7 |
| Norton (2004) ⁹² | Prosp CS | Titanium oxide grit-blasted | 25* (16) | - | 25* (12) | NR/Transmucosal | Immediate restoration/ Single-tooth restorations | Mean 20.3 mo (range 13 to 30 mo) In function for 15.7 mo (range 8 to 27 mo) | 97.6 | 95.2 |
| Godfredsen (2004) ⁹³ | Prosp CS | Titanium oxide grit-blasted | - | Group A: 10 (10) 4 wk after extraction Group B: 10 (10) 12 wk after extraction | - | e-PTFE membrane only/ Submerged | Delayed/Single-tooth restorations | 5 y | - | 100 |
| Evian et al (2004) ⁹⁴ | Retro CS | HA and turned | 100 (100) | 49 (49) (placement time after extraction NR) | - | NR/Submerged | Conventional/ Restoration type NR | Mean 2.6 y | 85 | 85.7 |
| Perry and Lenchewski (2004) ⁹⁵ | Retro CS | NR | 442* (322) | 442* (777) (8 to 12 wk after extraction) | - | NR/Submerged | Conventional/ Restoration type NR | 34.5 mo (range 5.8 to 67.4 mo) | 90 | 90 |

Table 6 continued Clinical Studies with Comparative Data on Survival Outcomes with Different Implant Placement Times After Extraction

| Study | Study design | Implant surface | No. of patients (No. of implants) | | | | Augmentation method (healing protocol) | Loading protocol/restoration type | Observation period | Survival rate (%) | |
|---|--------------|------------------------------------|--|-------------------------------------|--|---|--|-----------------------------------|--------------------|-------------------|-----------------------|
| | | | Type 1 | Type 2 and 3 | Type 4 | Type 1 and 3 | | | | Type 2 | |
| Schropp et al (2005) ⁸⁷ | RCT | Acid-etched | 23 (23) Mean 10 d after extraction (range 3–15 d) | 23 (23) (3 mo after extraction) | - | Type 1—no augmentation; Type 3—autogenous bone particles if defects present/Submerged | Conventional/Single-tooth restorations | 2 y | 91 | 96 | - |
| Degidi et al (2006) ⁹⁶ | Prosp CS | Mixed: turned, TPS and acid-etched | 67 (67) | - | 44 (44) | NR/Transmucosal | Immediate restoration/Single-tooth restorations | 5 y | 92.5 | - | 100 <i>P</i> < .05 |
| Lindeboom et al (2006) ⁸⁸ | RCT | SBE | 25 (25) | 25 (25) (12 wk after extraction) | - | Particulate autogenous cancellous bone and resorbable collagen membrane/Submerged | Delayed/Single-tooth restorations | 12 mo | 92 | 100 | - |
| Fugazzotto et al (2007) ⁹⁷ | Retro CS | SLA | 22 (39) | - | 39 (130) All patients on bisphosphonate therapy (658) | DeminerIALIZED bone matrix blocks with type 1 placement, and resorbable or e-PTFE membranes | NR | 12 to 24 mo | 100 | - | 100 |
| Degidi et al (2007) ⁹⁸ | Retro CS | Various surfaces | 1,064* (416) | - | 1,064* (658) | NR/Transmucosal | Immediate restoration/Restoration type NR | Mean 3 y | 90.2 | - | 93.9 |
| Siegenthaler et al (2007) ⁹⁹ | Prosp CCT | SLA | 34 (34) | - | - | DBBM and resorbable collagen membrane | Conventional/Single-tooth restorations | 12 mo | 100 | - | - |
| Horwitz et al (2007) ⁹⁹ | | Sandblasted and acid-etched | 19* (41) | - | 19* (33) | NR/Transmucosal | Immediate loading/Single-tooth, partial and full-arch restorations | 12 mo | 65 | - | 94 |

Study design: Prosp = prospective; Retro = retrospective; RCT = randomized controlled trial; CCS = controlled clinical study; CoS = cohort study; CS = case series. Implant surface: Turned = equivalent to machined surface; TPS = titanium plasma-sprayed; HA = hydroxyapatite-coated; SLA = sandblasted with large-sized grit and acid-etched surface; SBE = sandblasted and acid-etched. Placement time after extraction: Type 1 = immediate placement at the time of extraction; Type 2 = early placement after initial soft tissue healing; Type 3 = early placement after substantial bone healing; Type 4 = late placement after complete healing of the ridge. Augmentation method: e-PTFE = expanded polytetrafluoroethylene membrane; DBBM = deproteinized bovine bone mineral; DFDBA = demineralized freeze-dried bone allograft; HA = hydroxyapatite. Loading protocols according to the ITI Consensus Conference (2003).¹²⁴ -- = due to the study design, there were no data for this parameter. NR = not reported.

*Indicates total number of patients in the study.

¹This study represents the 5-year follow-up; 3-year results were published in Grunder et al (1999).¹²⁷

Type 2 Versus Type 3 Implant Placement. One study compared the outcomes of 10 implants placed 4 weeks after extraction in 10 patients, with 10 implants placed 12 weeks after extraction in another group of 10 individuals.⁹³ The survival rate was 100% for both groups after 5 years of function. One RCT compared the outcomes of different early placement times over a 2-year observation period.⁸⁷ A total of 46 subjects each received a single implant, either 3 to 15 days (mean 10 days) or 3 months after extraction (type 3 placement). The survival rates were 91% for type 2 and 96% for type 3. It should be noted that implant placement between 3 and 15 days after extraction is unlikely to have been accompanied by complete soft tissue healing, and therefore does not fulfill the definition of early placement with soft tissue healing (type 2) adopted in this review.

Does Implant Surface Affect Implant Survival? A variety of implant surfaces were used in the studies reviewed, with many studies reporting the use of mixed implant systems and surfaces. Implants with a machined surface were widely used prior to the year 2000; subsequently, the majority of studies utilized roughened surfaces. Survival rates for machined implant surfaces ranged from 93.6% to 100% (median 95%).^{25,39,51,59,65,66,68,86} Survival rates for hydroxyapatite (HA)-coated implants were 82.4% to 100% (median 99.5%).^{53,58,73,76} Survival rates reported in studies that used implants with a titanium plasma-sprayed surface (TPS) ranged from 94.5% to 100% (median 97%).^{27,52,56,67} In studies using implants with a sandblasted and acid-etched surface (SLA), survival rates of 99.1% to 100% (median 100%) were reported.^{23,60,70,77,79,89,97,100,101}

Due to differences in study design and follow-up periods, no direct conclusions can be drawn from the data. However, there was a trend toward slightly lower survival rates for implants with a machined surface (median survival rate 95%) and highest survival rates for implants with an SLA surface (median survival rate 100%). No studies were designed to compare the survival of implants with different surfaces in postextraction sites. One retrospective study reported no differences in survival outcomes between implants with machined and roughened surfaces.⁸¹

Does Systemic Antibiotic Therapy Improve Survival Outcomes? The majority of studies reported that systemic antibiotics were prescribed. However, the antibiotic regimen varied considerably between studies. Penicillin was the most common antibiotic prescribed. There were no studies that evaluated survival outcomes with and without systemic antibiotic therapy. In one retrospective study, implant survival was significantly influenced by choice of antibiotics.⁸¹ Fail-

ure rates were higher in patients who were allergic to penicillin and were prescribed alternative antibiotics.

What Are the Potential Risk Indicators for Survival of Postextraction Implants? Several factors have been considered as potential risk indicators for failure of postextraction implants.

Chronic Periodontitis. In a retrospective study of 1,091 implants in 591 patients who were observed for a period of 1 to 11 years, an overall survival rate of 95% was reported.⁸¹ The authors reported that there were significantly more failures in men than in women, in those who were prescribed alternative antibiotics to penicillin, in implants in mandibular anterior sites, and in tooth sites with chronic periodontitis. Three other studies identified chronic periodontitis as a risk indicator.^{51,65,94} A higher failure rate was also noted in periodontitis sites irrespective of the timing of placement after extraction.^{65,94} In a study of implants placed into 76 extraction sites with infection (55 chronic periodontitis, 15 endodontic pathology, and 6 root fractures) in 33 patients, two implants failed during the 12-month follow-up. The failed implants were in sites affected by chronic periodontitis.⁸⁴

Periapical Pathology. The data for survival of implants in sites with apical pathology are contradictory. Two controlled studies have been published comparing sites with periapical pathology. In the RCT of Lindeboom et al described previously, the authors reported that the survival rate was lower for type 1 compared to type 3 implant placement.⁸⁸ In a controlled clinical study, type 1 implant placement was compared in 17 tooth sites with apical pathology and 17 sites without apical pathology in 32 subjects.⁸⁹ After 12 months, the survival rates for both groups were 100%. It should be noted that 5 sites (4 with apical pathology and 1 without apical pathology) were withdrawn due to lack of initial implant stability.

Immediate Loading. The data on survival of immediately loaded implants placed into postextraction sites are unclear. Although high survival rates ranging from 91% to 100% (median 100%) were reported in a number of prospective case series studies of immediate restoration of single-tooth, short-span, and full-arch cases,^{55,56,64,70,76,78,80,102} comparative studies have reported lower survival rates of 65% to 100% (median 91%) for type 1 implants compared to 94% to 100% (median 95%) for implants with type 4 placement for similar clinical indications.^{53,66,92,96,98,99} In a study in which implants were placed into extraction sockets of teeth with chronic periodontitis, a much lower survival rate was observed with type 1 placement (65%) compared to implants placed into healed (type 4) placement sites (94%).⁹⁹

Implant Sites. The majority of reports with type 1 placement were confined to single-root extraction

sites in the maxillary and mandibular anterior and premolar regions. Several studies provided data on implants placed into multirroot extraction sites.^{60,63,69,79,100,101} The survival rates of 89% to 100% (median 99.5%) were similar to the results for implants in single-root extraction sites.

Systemic Risk Factors. One study reporting on the effect of systemic conditions on postextraction implant survival was identified.⁹⁷ In this retrospective study comparing type 1 and type 4 implant placement, no postoperative complications or implant failures were observed in 61 patients who were on oral bisphosphonate therapy.

Esthetic Outcomes of Postextraction Implants

Esthetic outcomes of postextraction implants were reported in 17 prospective^{20,50,56,66,70,72,76–78,82,83,86,88,93,103–105} and 7 retrospective studies.^{11,80,106–110} (Table 7).

Esthetic outcomes were reported as changes in the position of the midfacial mucosa and papillae, width of keratinized mucosa, radiographic location of the proximal bone, esthetic indices, and patient- and clinician-rated esthetic results. The majority of studies reported on outcomes with single-tooth implant restorations, predominantly in the maxillary anterior and premolar regions.

The majority of studies were short term, with follow-up periods of 12 to 24 months. Three studies reported on esthetic outcomes after mean observation periods of 4 to 5 years.^{20,78,93} One study provided data on a subset of patients who were followed for 6 to 9 years.¹⁰⁶

What Tissue Alterations Occur with Postextraction Implants? Changes in the level of the midfacial mucosa and height of the papillae have been reported in studies using different placement protocols.

Midfacial Mucosa. Three studies reported that mean recession of the midfacial mucosa ranging from 0.5 to 0.9 mm (median 0.75 mm) occurred with type 1 implant placement.^{70,76,107} One of these studies used an immediate restoration protocol in which implants were placed without elevation of surgical flaps.⁷⁶ In a retrospective study of type 1 implant placement without flap elevation in 85 single maxillary central and lateral incisor sites in 85 patients, mean recession of 4.6% of the length of the adjacent maxillary central incisor was reported.¹¹⁰ With type 2 placement, one study reported 0.6 mm of recession of the facial mucosa.⁸⁶ In a study comparing type 2 and type 3 placement, mean recession of 0.6 mm and 0.7 mm was reported, respectively. Over 5 years, further recession of 0.3 mm occurred in the type 2 placement group, whereas a reduction in recession of 0.3 mm was observed in the type 3 placement

group.⁹³ These dimensional changes are similar to those found in reports of single-tooth implants in healed sites (type 4 implant placement).^{111–113}

In addition to mean values, which express the magnitude of change, frequency analyses provide a useful way to examine the trends in soft tissue recession.¹⁰⁷ Frequency of recession with type 1 placement was reported in eight studies.^{20,50,83,88,103,104,107,110} Recession was reported in a high proportion of sites, ranging from 8.7% to 45.2% (median 39%). Five studies reported that recession of 1 mm or greater was observed in 8% to 40.5% (median 21.4%) of sites.^{50,83,88,103,107} In one study in which type 1 implants were placed without elevation of surgical flaps and restored 3 months later, recession of more than 10% of the length of the adjacent reference maxillary central incisor occurred in 18% of sites.¹¹⁰

One retrospective case series study with 45 single-tooth implants using early placement (type 2) showed a low incidence of recession after 2 to 4 years of follow-up.¹¹ This low incidence of recession was confirmed in a prospective study of type 2 placement by the same authors.⁷² Only one out of 20 sites (5%) exhibited recession, and this was between 0.5 and 1.0 mm. In contrast, a prospective pilot study comparing type 2 and type 3 placement reported a much higher frequency of recession in both treatment groups. The authors observed that the clinical crowns of the implant restorations were longer than the contralateral natural teeth in 9 of 10 and 8 of 10 sites, respectively. The difference in frequency of recession reported in these studies may be due to the different approaches to bone augmentation used by the authors. Gotfredsen used e-PTFE membranes when defects of the facial bone were present, but with no adjunctive bone grafts.⁹³ In addition, the utilization of e-PTFE membranes required a second open flap procedure for membrane removal, causing additional morbidity and local bone resorption. In contrast, Buser and coworkers grafted the peri-implant defects and external surfaces of the facial bone with DBBM and covered the graft with a resorbable collagen membrane, which did not require a second open-flap procedure.^{12,72} DBBM is a xenograft reported to have a low substitution rate¹¹⁴ and therefore exhibits low dimensional change over time.

There were three studies of type 1 placement with immediate restoration that reported on changes to the midfacial mucosa. Kan et al reported that mean recession of 0.5 ± 0.53 mm occurred after 12 months.⁷⁶ Wohrle observed that recession of 1 mm to 1.5 mm occurred in 2 out of 14 (14.3%) sites.¹⁰³ In a prospective study in which type 1 implants with defects of the facial aspect were immediately restored, recession of greater than 1.5 mm was

Table 7 Clinical Studies Reporting on Esthetic Parameters with Postextraction Implants

| Study | Study design | Placement protocol | Healing protocol/loading protocol | No. of patients (No. of implants) | Change in midfacial mucosa | | Change in papillae height | Esthetic outcomes |
|--|--------------|--|------------------------------------|------------------------------------|----------------------------|--|--|---|
| | | | | | Follow-up period | Frequency | | |
| Wohrle (1998) ¹⁰³ | Prosp CS | Type 1 | Transmucosal/Immediate restoration | 14 (14) | 1 to 3 y | 14.3%; recession 1 to 1.5 mm | NR | NR |
| Grunder (2000) ⁸⁶ | Prosp CS | Type 1 | Submerged/Delayed | 10 (10) | 12 mo | NR | Mean recession of papilla 0.4 mm (median 0.5 mm; range 0 to 1.5 mm) | NR |
| Kan et al (2003) ⁷⁶ | Prosp CS | Type 1 | Transmucosal/Immediate restoration | 35 (35) | 12 mo | NR | 0.5 ± 0.53 mm | Patient evaluation of esthetic outcome (Rating 0 to 10; 0 = totally unsatisfied, 10 = totally satisfied): 33/35 patients were totally satisfied with the esthetic outcome (rated 10) 2/35 patients rated the outcome as 9 Mean patient-rated esthetic outcome 9.9 |
| Malo et al (2003) ⁸⁶ | Prosp CS | Type 1 | Transmucosal/Immediate restoration | 67 (85) | 12 mo | Mucosal recession observed in 1 patient | NR | Dentist evaluation at 1 y: Excellent 18/67 patients Good 41/67 Acceptable 6/67 Unacceptable 2/67 Patient evaluation at 1 y: All patients were satisfied with the esthetic outcome |
| Bianchi and Sanfilippo (2004) ¹⁰⁶ | Retro CS | Type 1 | Submerged/Delayed | 22 (22) test sites (control sites) | 6 to 9 y | 6- to 9-year follow-up: Recession > 1 mm in 5% of test and 20% of control sites | NR | NR |
| Goffredsen (2004) ⁹³ | Prosp CS | Type 2 (4 wk after extraction) and Type 3 (12 wk after extraction) | Submerged/Delayed | Type 2: 10 (10) Type 3: 10 (10) | 5 y | Recession at baseline: Type 2: 9/10 crowns longer than control tooth Type 3: 8/10 crowns longer than control teeth | Type 2: 0.6 ± 1.2 mm increased by 0.3 ± 0.5 mm after 5 y Type 3: 0.7 ± 1.4 mm reduced by 0.3 ± 0.6 mm after 5 y | Patient evaluation based on a Visual Analog Scale (VAS): Type 2: 9.8 (range 9.1-10.0) Type 3: 8.8 (range 5.1-10.0) Dentist evaluation using the same VAS: Type 2: 5.9 (range 2.9-9.5) Type 3: 8.4 (range 6.1-9.7) |

Table 7 continued Clinical Studies Reporting on Esthetic Parameters with Postextraction Implants

| Study | Study design | Placement protocol | Healing protocol/loading protocol | No. of patients (No. of implants) | Follow-up period | Change in midfacial mucosa | | Change in papillae height | Esthetic outcomes |
|--|--------------|------------------------------------|------------------------------------|---|------------------|---|--|--|--|
| | | | | | | Frequency | Mean | | |
| Cangini and Cornelini (2005) ⁷⁷ | Prosp CCS | Type 1 | Transmucosal/Delayed | 32 (32) | 12 mo | NR | 0.2 ± 1.5 mm at sites treated with enamel matrix derivative and 0.9 ± 1.3 mm at sites with collagen membrane | NR | NR |
| Cornelini et al (2005) ⁷⁰ | Prosp CS | Type 1 | Transmucosal/Immediate restoration | 22 (22) | 12 mo | NR | Mean recession 0.75 mm | Jemt Papilla Index*: Score 2: 61% of papillae Score 3: 39% of papillae No scores of 0, 1, and 4 | NR |
| Schropp et al (2005) ¹⁰⁴ | RCT | Mean 10 d postextraction Type 3 | Submerged/Conventional | Mean 10 d postextraction 23 (23) Type 3: 23 (23) | 2 y | 8.7% exposure of metal margin | NR | Jemt Papilla Index*: Score 2: 33% of papillae Score 3: 8% of papillae | All patients were highly satisfied with the esthetic outcome |
| Barone et al (2006) ⁵⁶ | Prosp CS | Type 1 | Transmucosal/Immediate restoration | 18 (18) | 12 mo | Width of keratinized mucosa 3.3 ± 0.5 mm; no significant change from baseline | NR | NR | All patients were satisfied with the esthetic outcome |
| Lindeboom et al (2006) ⁸⁸ | RCT | Type 1 and Type 3 | Submerged/Delayed | Type 1: 25 (25) Type 3: 25 (25) | Mean 12.4 mo | 26% sites with recession No recession in 56% of type 1 placements and 84% of type 3 Recession 0 to 1 mm in 28% of type 1 placements and 16% of type 3 Recession 1 to 2 mm in 8% of type 1 placements (none for type 3) | NR | Jemt Papilla Index*: Score 2 in 22% of type 1 and 28% of type 3 implant placement sites Score 3 in 78% of type 1 and 72% of type 3 implant placement sites | NR |
| De Kok et al (2006) ⁸⁰ | Retro CS | Type 1 | Transmucosal/Immediate restoration | 20 (25) | 6 to 30 mo | NR | NR | Jemt Papilla Index*: Score 1: 64% of papillae Score 2: 32% of papillae Score 3: 4% of papillae | NR |
| Ferrara et al (2006) ⁷⁸ | Prosp CS | Type 1 | Transmucosal/Immediate restoration | 33 (33) | 4 y | NR | NR | Papillae when initially present were never lost | Patient-rated esthetic outcome; Score of 9.3 ± 0.65 (using a 10-point scale, with 0 = completely unsatisfactory and 10 = completely satisfactory) |
| Chen et al (2007) ²⁰ | RCT | Type 1 | Submerged/Conventional | 19 (19) | 4 y | 33.3% of sites with recession | NR | NR | NR |
| Juozbalyas and Wang (2007) ⁸³ | Prosp CS | Type 1 | Submerged/Delayed | 12 (14) | 12 mo | 21.4% with recession of 1 to 2 mm | NR | Jemt Papilla Index*: Score 2: 64% of papillae Score 3: 36% of papillae | Pink Esthetic Score (PES) [†] of 11.1 64.3% of cases with incomplete mesial and distal papillae 42.9% of cases with alveolar process deficiency |

Table 7 continued Clinical Studies Reporting on Esthetic Parameters with Postextraction Implants

| Study | Study design | Placement protocol | Healing protocol/loading protocol | No. of patients (No. of implants) | Change in midfacial mucosa | | | Change in papillae height | Esthetic outcomes |
|---------------------------------------|--------------|--------------------|------------------------------------|-----------------------------------|---|------------------------------|---|--|-------------------|
| | | | | | Frequency | Mean | Follow-up period | | |
| Covani et al (2008) ⁸² | Prosp CS | Type 1 | Submerged/Delayed | 10 (10) | Mean 4.1 mm width of keratinized mucosa on the facial aspect | NR | NR | NR | |
| Kan et al (2007) ⁵⁰ | Prosp CS | Type 1 | Transmucosal/Immediate restoration | 23 (23) | 34.8% recession ≥ 1.5 mm; 8.3% of sites with V-shaped defects of the facial bone* 42.8% of sites with U-shaped defects of the facial bone; 100% of sites with U-shaped defects of the facial bone | NR | NR | NR | |
| Steigmann et al (2007) ¹⁰⁵ | Prosp CS | Type 1 | Transmucosal/Immediate restoration | 10 (10) | NR | NR | 9/10 sites with slight blunting of the papillae | All patients extremely satisfied with the esthetic outcome | |
| Evans and Chen (2008) ¹⁰⁷ | Retro CS | Type 1 | NR/Conventional | 42 (42) | Mean 45.2% recession 0.5 mm 21.4% recession 1.0 mm 19.1% recession ≥ 1.5 mm | Mean recession 0.9 ± 0.78 mm | Mean recession of papilla 0.5 ± 0.52 mm (mesial); 0.5 ± 1.0 mm (distal) | Subjective Esthetic Score (SES) [§] 82% satisfactory (scores I and II) 18% unsatisfactory (scores III and IV) | |
| Degidi et al (2008) ¹⁰⁸ | Retro CS | Type 1/ Type 4 | Transmucosal/Immediate restoration | 45 (52) | NR | NR | Jemt Papilla Index for type 1 and type 4 implant placement combined: Score 1: 14.5% of papillae Score 2: 50% of papillae Score 3: 35.5% of papillae | NR | |
| Degidi et al (2008) ¹⁰⁹ | Retro CS | Type 1 | Transmucosal/Immediate restoration | 49 (152) | NR | NR | Combined Jemt Papilla Index scores 2 and 3 decreased when two implants were placed ≥ 4 mm apart when the bone crest to contact point between to implant crowns was > 6 mm | Multiple adjacent implants | |
| Buser et al (2008) ¹¹¹ | Retro CS | Type 2 | Submerged/Early | 45 (45) | NR | NR | NR | No recession of the midfacial mucosa was observed | |
| Buser et al (2009) ⁷² | Prosp CS | Type 2 | Submerged/Early | 20 (20) | Mean difference between test and contralateral natural teeth 0.18 mm One site with recession of 0.5 to 1.0 mm | NR | NR | Mean modified PES of 8.1 (out of 10) Mean WES of 8.65 (out of 10) | |

Table 7 continued Clinical Studies Reporting on Esthetic Parameters with Postextraction Implants

| Study | Study design | Placement protocol | Healing protocol/loading protocol | No. of patients (No. of implants) | Follow-up period | Change in midfacial mucosa | | Change in papillae height | Esthetic outcomes |
|----------------------------------|--------------|--------------------|-----------------------------------|-----------------------------------|------------------|---|-------------------------------|---|---|
| | | | | | | Frequency | Mean | | |
| Chen et al (2009) ¹¹⁰ | Retro CS | Type 1 | Transmucosal/ Early | 85 (85) | 26 mo | At 44 sites with initial gingival margins level with adjacent maxillary central incisor: 20.5% recession 5 to 10%; 18% recession of > 10% | Mean recession of 4.6 ± 6.6%# | Mean recession of papillae 6.2% ± 6.8% (mesial)##; 7.4% ± 7.5% (distal)## | Subjective Esthetic Score (SES) [§] 42.4% good (score I) 38.8% acceptable (score II) 9.4% unsatisfactory (scores III and IV) Mean PES [†] of 10.95 (out of 14) 21.2% optimum (scores 13 and 14) 56.5% good (scores 10 to 12) 22.3% suboptimal (score 8 or 9) |

Study design: Prosp = prospective; Retro = retrospective; RCT = randomized controlled trial; CCS = controlled clinical study; CS = case series.

Placement time after extraction: Type 1 = immediate placement at the time of extraction; Type 2 = early placement after initial soft tissue healing; Type 3 = early placement after substantial bone healing; Type 4 = late placement after complete healing of the ridge.

Augmentation method: e-PTFE = expanded polytetrafluoroethylene membrane; DBBM = deproteinized bovine bone mineral; DFDBA = demineralized freeze-dried bone allograft; HA = hydroxyapatite.

Loading protocols according to the ITI Consensus Conference (2003).¹²⁴

NR = not reported.

#Papilla Index Score as described by Jemt (1997).¹¹⁸

[†]PES = Pink Esthetic Score of Furhauser et al (2005): Seven variables assessed in relation to reference tooth and assigned scores of 0, 1, or 2 out of a total possible score of 14, for i, shape of mesial papilla; ii, shape of distal papilla; iii, level of soft tissue margin; iv, soft tissue contour; v, alveolar process deficiency; vi, soft tissue color; vii, soft tissue texture.¹²¹

[‡]Dehiscence defect on facial aspect of the implant classified as: V-shaped, narrow defect isolated to facial surface of implant only; U-shaped, wide defect extending proximally into the mesial or distal aspects of the tooth to be extracted; UU defect, wide defect extending to and including the mesial or distal surfaces of the adjacent teeth.¹⁰²

[§] Subjective Esthetic Score (SES):¹⁰⁷ I = vertical facial change was 0.5 mm or less and labial tissue fullness was in harmony with the adjacent teeth; II = vertical facial change was between 0.5 and 1.0 mm and the facial tissue fullness was in harmony; III = vertical facial change was between 1.0 and 1.5 mm or the facial tissue appears deficient in contour; IV = vertical facial change was greater than 1.5 mm and a deficiency in facial tissue contour was noted.

|| Modified Pink Esthetic Score (modPES) of Furhauser et al (2005)¹²¹: Five variables assessed in relation to reference tooth and assigned scores of 0, 1, or 2 out of a total possible score of 10, for i, shape of mesial and distal papillae; ii, level of soft tissue margin; iii, soft tissue contour; iv, alveolar process; v, soft tissue color and texture.

[¶] White Esthetic Score (WES): Scores of 0, 1, and 2 assigned out of a total possible score of 10; for i, tooth form; ii, tooth volume/outline; iii, color; iv, surface texture; and v, translucency.⁷²

[#] Tissue level change expressed as a percentage of the length of the adjacent maxillary central incisor which served as the reference.

observed in 34.8% of sites.⁵⁰ Chen et al observed that mucosal recession occurred soon after restoration of the implants, and then remained stable between the 1-year and 3-year recall periods.²⁰

One RCT compared type 1 and type 3 placement in sites with radiographic evidence of chronic periapical periodontitis.⁸⁸ Absence of recession was noted in only 56% of immediate implant (type 1) sites, compared to 84% for early placement (type 3). Recession of 1 to 2 mm was observed in 8% of type 1 implant sites. In contrast, there were no sites with recession of 1 to 2 mm in the type 3 placement group.

In an RCT comparing implant placement soon after tooth extraction (mean 10 days) with early placement after partial bone healing (type 3), recession of the mucosal margin resulting in exposure of the metal margin of the implants was observed in 8.7% of implants in each of the two groups after 2 years.¹⁰⁴ The height of the implant crowns was subjectively determined to be too long in 17% of the 10-day postextraction sites and 20% of type 3 implant placement sites, and too short in 30% of type 3 implant placement sites. The crowns were of an appropriate height in 83% of the 10-day postextraction sites and only 50% of type 3 implant sites.

Data on long-term outcomes are limited. However, one study provided data on a subset of patients who were followed for 6 to 9 years, with implants placed in both anterior and posterior sites.¹⁰⁶ Twenty-two patients received 22 single-tooth type 1 implants that were submerged at the time of surgery using connective tissue grafts. Twenty patients with 20 immediate implants that were placed without the use of connective tissue (CT) grafts served as controls. Between 6 and 9 years following surgery, the proportion of sites with recession greater than 1 mm (in relation to adjacent teeth) was 5% in test sites compared to 20% in control sites. It was not possible to distinguish between anterior and posterior sites from the study.

From these studies, it can be concluded that recession of the midfacial mucosa, even when combined with grafts of bone or bone substitutes, is a common complication with type 1 placement. The recession occurs soon after restoration of the implants. Recession of 1 mm or more was observed in a high proportion (range 8% to 40.5%; median 21.4%) of sites. This dimensional change may lie within the visual threshold of detecting a difference in mucosal levels.¹¹⁵ Mucosal recession would therefore be expected to have an adverse effect on esthetic outcomes, as most studies reported that implants were placed in the maxillary anterior and premolar sites. Recession was also observed with immediate restoration of implants, and implants placed without elevation of surgical flaps.

Early placement (type 2 and type 3) may also be associated with recession. However, there is evidence to suggest that early placement with soft tissue healing (type 2) is associated with a relatively low incidence of recession when implant placement is combined with GBR procedures using DBBM. There is evidence that early placement with partial bone healing (type 3) is associated with a lower frequency of recession compared to type 1 placement.

Papillae. With type 1 placement, a mean loss of papilla height of between 0.5 and 0.6 mm was reported in three studies.^{76,86,107} Changes in papilla height were similar for conventional loading and immediate restoration protocols. In a prospective study of type 1 placement using the crown of the natural tooth as an immediate restoration, slight blunting of the papilla was reported in 9 out of 10 treated sites.¹⁰⁵ In a retrospective study of type 1 placement with immediate restoration, 64% of sites achieved a satisfactory papilla form.⁸⁰ Loss of papilla height was accompanied by a reduction in the height of the proximal crestal bone of 0.3 to 1.9 mm (median 1.2 mm).^{56,66,70,76,83,105} Less than ideal papilla fill was reported for adjacent implants when the interimplant distance was less than 2 mm.¹⁰⁹

Four studies used the Papilla Index of Jemt to describe the form of the papillae with immediate placement.^{70,83,88,108} The results were variable. In the four studies, a score of 3 (indicating complete fill of the proximal embrasure space) was recorded in 35% to 78% (median 37%) of sites. A score of 2 (indicating that half or more of the papilla height was present, but not 100%) was recorded in 22% to 64% (median 55%) of sites. A score of 1 (indicating that less than half of the papilla height was present) was only recorded in one study, affecting 14.5% of sites¹⁰⁸; three studies reported that no sites recorded a score of 1. In studies of immediate restoration of implants^{70,108} there was no clear advantage over studies using conventional loading protocols^{83,114} according to this index.

Two studies provided comparative data on different placement times after extraction. One RCT reported that the risk of a missing papilla or negative papilla form at the time of restoration was 7.2 times greater for type 3 compared to type 2 implant placement (33% of sites vs 8% of sites, respectively).¹⁰⁴ However, after 1.5 years there was no difference between the groups (8% for type 2 placement and 3% for type 3 placement). Overall, 5% of sites had a score of 0, 35% had a score of 1, and 60% had a score of 2. Another RCT comparing type 1 and type 2 implant placement showed no difference between treatment groups.⁸⁸ Studies of type 4 implant placement have reported similar variations in papilla fill.^{116,117}

The main disadvantage of the Papilla Index of Jemt¹¹⁸ is that scores are based on the degree of fill of the embrasure space after the crown has been attached to the implant, and not on a comparison with the pretreatment form and height of the papilla prior to tooth extraction. Implant crowns will often have an altered width and contact area to compensate for a reduction in height of the papilla.¹¹⁹ This makes it difficult to compare results between studies with this index. Several studies reported that the form of the papilla improved over time with postextraction implants,^{80,104} a phenomenon also reported with type 4 placement.¹¹⁶⁻¹¹⁸

The results of these studies show that type 1 placement is associated with recession of the papillae. The majority of sites achieved fill of the interproximal embrasure space of at least half of the height, but achieving complete fill was variable. There is evidence to suggest that the final form of the papillae with type 1 placement using immediate restoration and conventional loading is similar. Similar outcomes have been reported with type 4 placement. Two RCTs provide strong evidence that the final form of the papillae is independent of the timing of implant placement after tooth extraction.

Width of Keratinized Mucosa. Three studies reported on the width of the keratinized mucosa on the facial aspect following type 1 placement. The mean width was 3.3 mm and 4.1 mm in two studies.^{56,82} In a third study, 92.9% of sites had a width of keratinized mucosa greater than 2 mm.⁸³ These dimensions are in accord with studies of type 4 implant placement.^{116,119} The width of keratinized mucosa was greater when type 1 implants were submerged using connective tissue (CT) grafts, compared to sites that did not receive CT grafts.¹⁰⁶

What Factors Are Associated with Recession of the Mucosa? Several factors have been associated with recession of the peri-implant mucosa.

Tissue Biotype. With type 1 placement, sites with a thin tissue biotype had a higher frequency of recession of > 1 mm than sites with a thick tissue biotype.^{20,76,107}

Facial Bone Wall. Kan et al reported that damage to the facial bone wall encountered at the time of type 1 placement represented a significant risk factor for mucosal recession.⁵⁰ In 23 patients, implants were placed into fresh extraction sites with a damaged facial bone wall. The defects were grafted with DBBM and covered with a resorbable membrane. The results indicate that the risk of recession increased with the width of the dehiscence of the facial bone. Only 8.3% of sites with narrow (V-shaped) defects exhibited recession of 0.5 mm or more. Recession for sites with wide (U-shaped) defects and defects that involved

the adjacent teeth (UU-shaped defects) was 42.8% and 100%, respectively.

The thickness of the facial bone at the time of implant placement may be an important factor. In an RCT, Chen et al noted three residual defect types following type 1 placement.²⁰ Sites that healed with complete bone fill or a residual craterlike defect had an initial thickness of the facial bone of 0.7 to 0.9 mm and recorded vertical loss of crestal bone height of 0.3 to 0.9 mm at reentry. In contrast, sites that healed with a dehiscence defect initially had a facial bone thickness of 0.5 mm and recorded vertical crestal bone loss of 2.1 mm at reentry. Thus extraction sockets with thin facial bone lost more vertical height and had less bone fill than sites with thicker bone.

Orofacial Position of the Implant Shoulder. The orofacial position of the implant shoulder in the extraction socket with type 1 placement is strongly associated with mucosal recession. In three studies, implants that were placed facially within the sockets had a higher frequency and greater magnitude of recession than sites where implants were more palatally positioned.^{20,107,110} At sites with recession, the implants had a significantly greater orofacial defect depth of 2.3 mm compared to 1.1 mm for sites with no recession.²⁰ This is consistent with the observation that a peri-implant gap with type 1 implant placement is required to minimize compression of the facial bone wall on inserting the implant, and to allow bone regeneration in the gap to establish a thicker facial bone wall.¹²⁰ These clinical observations have been corroborated in an experimental study of implants in fresh extraction sockets in a canine model.⁴⁹ Less vertical crestal bone loss was observed when the peri-implant defects were wide, compared to sites where the defects were less than 2 mm in width.

What Are the Outcomes Based on Esthetic Indices? Esthetic indices were used in four studies. Based on the Pink Esthetic Score (PES),¹²¹ a mean score of 11.1 (out of a maximum 14) was reported in a prospective study of 14 immediate implants in 12 patients.⁸³ In this study, 64.3% of cases had incomplete fill of the papillae, and 42.9% had deficiencies in the alveolar process. In a retrospective study of 85 maxillary central and lateral incisors, a mean PES of 10.95 was recorded.¹¹⁰ Optimum esthetic results were achieved in 21.23% of sites (PES scores of 13 and 14). Suboptimal esthetic outcomes (PES scores of 8 and 9) were seen in 22.3% of sites. Using an alternative scoring system, 82% of sites had a satisfactory esthetic outcome with type 1 placement in a retrospective study of 42 implants in 42 patients.¹⁰⁷ A total of 18% of sites had an unsatisfactory outcome, mainly due to recession of the midfacial mucosa. In a prospective case series study with 20 single-tooth implants using

early placement (type 2), the 12-month results exhibited a mean modified PES index of 8.1, and a mean WES index of 8.65 (both out of a maximum of 10).⁷²

Studies reporting on patient-evaluated esthetic outcomes generally reported that patients were highly satisfied with the results with immediate (type 1) placement^{56,66,76,105} and early placement (type 2 and type 3)¹⁰⁴ irrespective of the loading protocol.

Although there has been increased interest in and reporting of esthetic outcomes with postextraction implants since the Third ITI Consensus Conference in 2003, there are still relatively few studies at the current time that evaluate esthetic outcomes using objective parameters.

CONCLUSIONS

Regenerative Outcomes of Postextraction Implants

From the studies reviewed, it can be concluded that:

- Bone augmentation procedures are effective in promoting bone fill and defect resolution in peri-implant defects following immediate (type 1) and early (type 2) placement.
- Peri-implant defects associated with immediate (type 1) and early (type 2) placement may heal spontaneously when the peri-implant defect is less than 2 mm in width and the facial bone wall is intact.
- Immediate placement does not prevent vertical or horizontal resorption of the ridges.
- Bone augmentation combined with immediate placement may reduce horizontal resorption, but does not prevent vertical resorption of the facial bone.
- Bone augmentation procedures are more successful in combination with immediate (type 1) and early (type 2 and type 3) placement compared to late placement (type 4).
- Evidence is lacking to demonstrate the superiority of one placement protocol over the other with respect to healing of peri-implant defects with postextraction implants. However, there is some evidence to show that regenerative outcomes are better with early placement (type 2) compared to immediate placement (type 1) in the presence of dehiscence defects of the facial bone wall.
- Postoperative complications are common with immediate placement.
- The efficacy of concomitant antibiotic therapy with regard to healing of postextraction implants has not been demonstrated.

Survival Outcomes of Postextraction Implants

- The survival rates for postextraction implants are high, with the majority of studies reporting rates of over 95%.
- Immediate (type 1) and early (type 2) placement protocols have similar survival rates.
- There is some evidence to suggest that implants with a machined surface have a lower survival outcome than implants with a roughened surface.
- There is no evidence to show that systemic antibiotics affect the survival outcome of postextraction implants.
- A history of chronic periodontitis is a risk indicator for survival of postextraction implants. The evidence for periapical pathology and immediate restoration as risk indicators is contradictory. Evidence for systemic factors as risks for implant survival is lacking.

Esthetic Outcomes of Postextraction Implants

- Tissue alterations leading to recession of the facial mucosa and papillae are common with immediate placement.
- There is evidence that early placement (type 2 and type 3) is associated with a lower frequency of mucosal recession compared to immediate placement (type 1).
- Risk indicators for recession with immediate placement include a thin tissue biotype, a facial malposition of the implant, and a thin or damaged facial bone wall.
- There is evidence to suggest that immediate restoration and conventional loading protocols appear to have similar outcomes with respect to soft tissue alterations.
- Although patient-evaluated esthetic outcomes with postextraction implants are generally favorable, there are relatively few studies that evaluate esthetic outcomes using objective parameters.

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