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Surgical treatment planning for the single-unit implant in aesthetic areas

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The clinical application of multiple implant-supported restorations in edentulous jaws has proven to be a predictable long-term treatment (1, 2). The implant-supported restoration has also been proposed for the replacement of the single tooth (48).

The single-tooth implant restoration has changed treatment planning of the missing tooth in the anterior sextant. Clinical situations in which single-tooth implants are considered the first option include 1) edentulous areas delimited by non-restored teeth, 2) edentulous areas delimited by intact restorations and 3) dentitions with diastemata (25).

The success rate of implant-supported single-tooth restorations is comparable to that of implant-supported prostheses in totally edentulous patients (Table 1). However, the goal of modern implant therapy in aesthetic areas is no longer represented just by the successful osteointegration of the implant. The final result has to be an implant-supported restoration surrounded by a soft and hard tissue environment in harmony with the existing dentition (82).

Although current dental technology allows creating artificial teeth perfectly matching the natural tooth, the soft and hard tissue surrounding the restoration cannot always be reconstructed. To pursue a predictable aesthetic result with the single-tooth implant, the practitioner needs to consider all the variables that influence the final outcome before the treatment is provided. Furthermore, surgical procedures must be performed precisely. An error in soft tissue management or implant positioning, despite the presence of a sufficient volume of soft tissue and bone, may lead to a major aesthetic failure.

This chapter discusses the surgical treatment planning of implant placement for a single-tooth restoration in aesthetic areas. Pre-surgical determinants, surgical procedures and treatment sequencing are reviewed, and a surgical protocol is introduced.

Pretreatment consideration

Pretreatment considerations include patient evaluation and implant site evaluation.

Patient evaluation

The patient evaluation should be comprehensive and consist of medical history and dental examination. The medical history must be evaluated for systemic conditions to prevent complications during the treatment. Non-controlled diabetes or chronic therapy with corticosteroid may alter the patient's healing ability and may jeopardize the surgical outcome. Smoking is a factor that may affect both implant osteointegration and the soft tissue healing.

The dental examination should consider active infections: caries, endodontic lesions and periodontitis. All the infective conditions should be treated before implant placement. Occlusal conditions are evaluated on a diagnostic cast. A diagnostic wax-up of the reconstructed site and radiographic examination should complete the documentation necessary for the surgical planning.

Implant site evaluation

To evaluate the implant site in aesthetic areas, the following determinants should be considered:

- smile line
- soft tissue morphology
- tooth morphology
- osseous architecture.

Table 1. Clinical studies on single-tooth implant restorations (chronological order)

Authors	Type of implant	*n*	Years of follow-up	No. of failed implants	Failure rate %
Jemt et al. (46)	Brånemark	107	1	3	2.8
Jemt et al. (47)	Brånemark	70	3	1	1.4
Laney et al. (56)	Brånemark	95	3	3	2.8
Ekfeldt et al. (29)	Brånemark	93	1–3	2	2.1
Andersson et al. (3)	Brånemark	65 37	2–3 3–4	1 1	1.5 2.7
Engquist et al. (30)	Brånemark	82	1–5	2	2.4
Haas et al. (38)	Brånemark	76	6	2	2.6
Malevez et al. (62)	Brånemark	84	5	2	2.3
Avivi-Arber & Zarb (7)	Brånemark	45	1–8	1	2.2
Henry et al. (41)	Brånemark	86	5	3	3.4
Karlsson et al. (53)	Astra	47	2	0	0
Kemppainen et al. (54)	Astra ITI	46 56	1	1 0	2.1 0
Palmer et al. (81)	Astra	15	2	0	0
Levine et al. (59)	ITI	174	6 months	4	2.3
Norton et al. (73)	Astra	27	6	0	0
Scheller et al. (89)	Brånemark	99	1–5	2	2
Moberg et al. (68)	ITI	30	3–4	1	3.3
Priest (83)	Brånemark	116	10	4	3.4
Levine et al. (60)	ITI	174	2	7	4.5
Thilander et al. (106)	Brånemark	15	8	0	0
Scholander (90)	Brånemark	259	1–9	10	1.7

Astra: Meditec, Mölndal, Sweden
Brånemark: Nobel Biocare AB, Göteborg, Sweden
ITI: The Straumann Co., Cambridge, MA

The smile line

The aesthetic zone is delimited by the lip perimeter. The amount of tooth surface and gingival tissue displayed during speech and smiling is determined by the tonus of the orofacial muscles that influence the movement of the upper lip (66). The average smile is described as the position of the lip showing 75% to 100% of the maxillary incisor and the interproximal gingiva (107). The high smile line differs from the average smile line because of additional exposure of gingival tissue. The low smile line exists when less than 75% of the maxillary teeth are displayed.

The high smile line poses greatest concern for implant-supported single-tooth restorations in the aesthetic area. The restoration and the gingival tissue will be completely displayed and the soft tissue contour, color and shape of the restoration have to be perfectly reconstructed to please the observer's eyes. The low smile line is a less critical situation for the implant-restoration interface, which will be hidden behind the upper lip.

The soft tissue morphology

The position of the gingival tissue around a tooth is determined by the connective tissue attachment level and by the bone level. Two different periodontal biotypes have been described in relation to the morphology of the interdental papilla and the osseous architecture (79, 113): the thin scalloped periodontium and the thick flat periodontium.

The thin scalloped periodontium is characterized by a thin and scalloped osseous housing of the tooth and by a thin gingival tissue with long interdental papillae. The thick and flat periodontium is characterized by a thick osseous structure and flat morphology, thick gingival tissue and short and wide papillae (13).

In health, the interdental papilla fills the embrasure space to the apical extent of the contact area. Periodontal disease or surgical trauma may lead to attachment loss or bone loss. The thin and scalloped periodontium has the tendency to develop soft tissue recession in response to trauma or peri-

odontal infection (78). The thick periodontal biotype is relatively resistant to surgical trauma and recession and the presence of periodontal infection leads most likely to pocket formation (79).

The recession of the interproximal soft tissue creates an empty space in the interdental area called a "black triangle". The loss of the interproximal soft tissue seems to correlate with the distance between the base of the contact area and the bone crest (105). For a distance equal to or less than 5 mm the interdental papilla is always present. For a distance of 6 mm and 7 mm or more, the interdental papilla fills the interproximal space in 56% and 27% of the time respectively.

The biological parameters determining the soft tissue position at the proximal site between a tooth and an implant have never been investigated. However, the level of papilla adjacent to a single implant is likely to be influenced by the periodontal attachment of the adjacent tooth (7).

The buccal soft tissue contour is critical for the natural appearance of the restoration. Two clinical situations may occur.

If the tooth is still present at the implant site, the buccal gingival dehiscence can be corrected by modifying the soft tissue morphology using orthodontic movement of the natural tooth. The forced eruption of the tooth will displace coronally both soft and hard tissue (43).

If the tooth has been extracted, hard and soft tissue remodeling takes place at the edentulous ridge. The ridge defect can be related to soft tissue collapse, bone resorption or combination of both. The extension of the defect dictates the surgical technique to be used for correction (96).

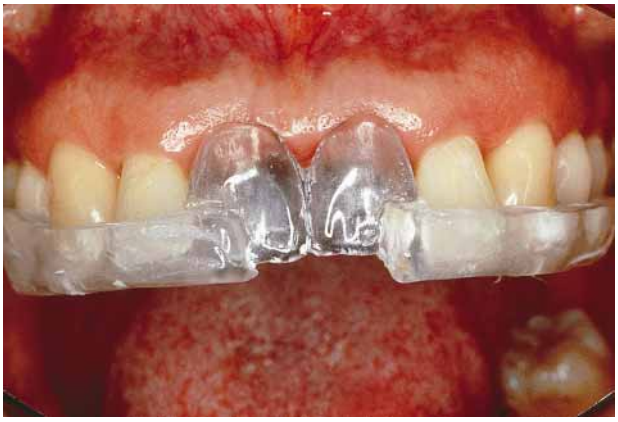


Fig. 1. The surgical guide duplicates the diagnostic wax-up. Tooth morphology and emergence profile should be reproduced and used as a reference point for the implant positioning.

The tooth morphology

The tooth morphology seems to be correlated with the soft tissue quality (78). The triangular tooth shape is present with the scalloped and thin periodontium. The contact area is located at the coronal third of the crown, underlining a long and thin papilla. The squared anatomic crown shape combines with a thick and flat periodontium. The contact area is located at the middle third supporting a short and wide papilla.

Loss of interproximal soft tissue in the presence of triangular shaped teeth will display a wider black triangle compared with the situation where a squared tooth is present. The tooth morphology can be modified to compensate for partial interproximal tissue loss. The contact area at the artificial tooth can be positioned more cervically, reducing the volume of the interdental space (82).

The maxillary central incisor measures on average 7–8 mm mesiodistally and 6 mm faciolingually at the emergence from the soft tissue (110). A standard 3.75-mm-diameter implant should be placed 3–4 mm apical to the buccal soft tissue level of the adjacent teeth (45) to allow the restoration to merge with a natural profile. A vertical distance of 3–4 mm is needed for a gradual transition from the 4-mm diameter of the implant platform to the 7- to 8-mm dimension of the crown at the gingival margin. If a maxillary lateral incisor is being replaced, the implant would not have to be positioned so far apically since the average diameter of the crown at the gingival level is 5 mm and less room for transition is needed.

A surgical guide is obtained from the diagnostic wax-up. The emergence profile and the shape of the restoration are reproduced on the guide to verify the implant position during placement (Fig. 1).

The bone morphology

The housing of a standard 3.75-mm-diameter implant requires 6 mm of bone in a buccolingual dimension and 5–6 mm in a mesiodistal dimension (18). Periodontal disease, endodontic infection and the bone remodeling process after tooth extraction may reduce the bone volume available for implant placement.

The loss of the vertical height of the bone at the implant site represents a limiting factor for achieving an aesthetic outcome. Orthodontic forced eruption (88), block bone grafting (J-graft) and osseous distraction (15, 33, 75, 76) have been proposed to cor-

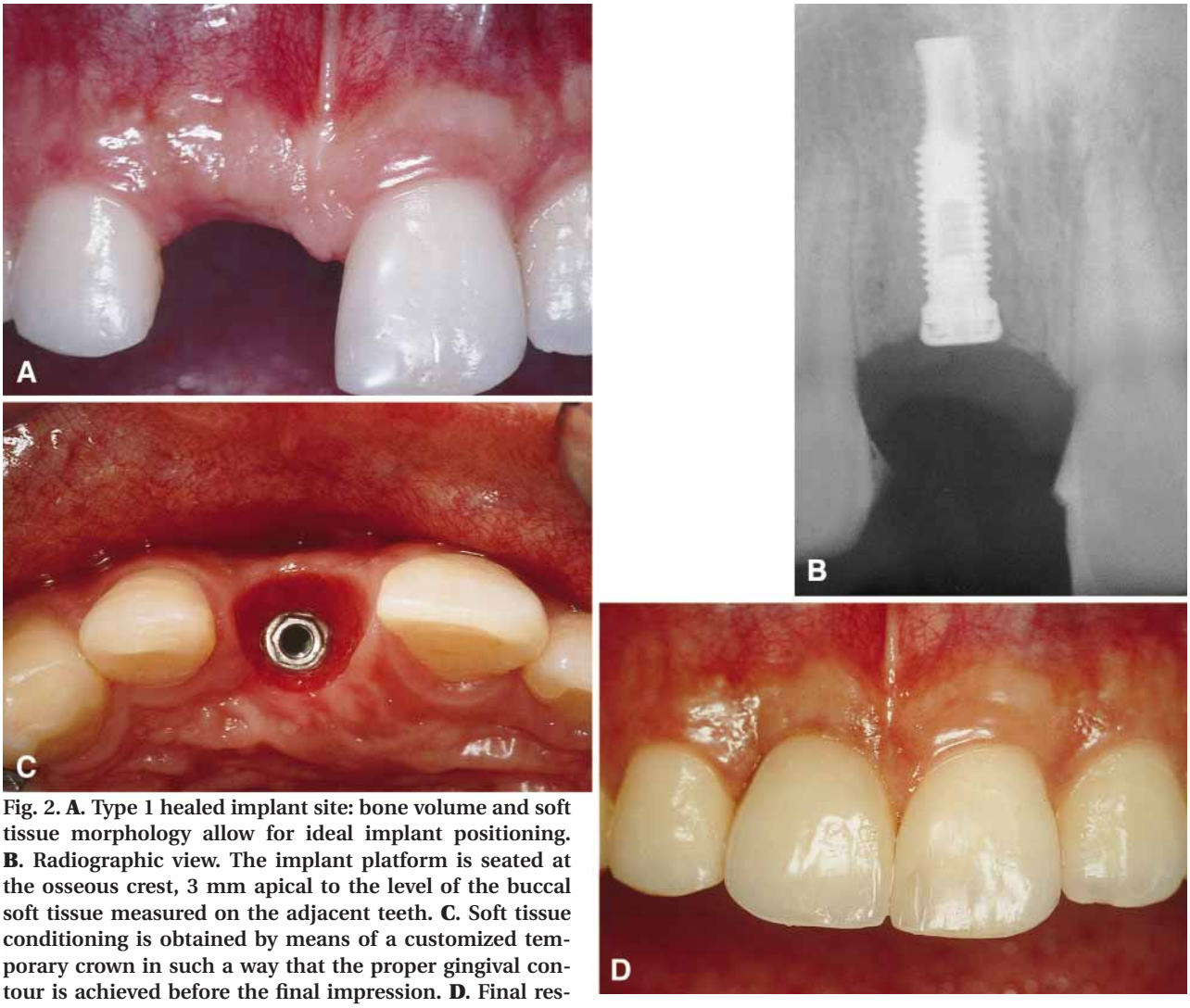


Fig. 2. A. Type 1 healed implant site: bone volume and soft tissue morphology allow for ideal implant positioning. **B.** Radiographic view. The implant platform is seated at the osseous crest, 3 mm apical to the level of the buccal soft tissue measured on the adjacent teeth. **C.** Soft tissue conditioning is obtained by means of a customized temporary crown in such a way that the proper gingival contour is achieved before the final impression. **D.** Final restoration in place.

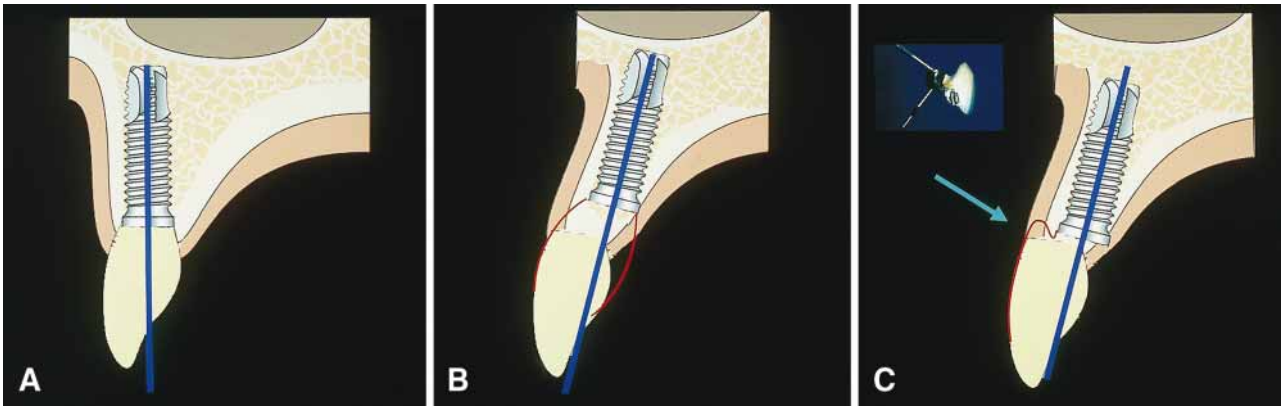
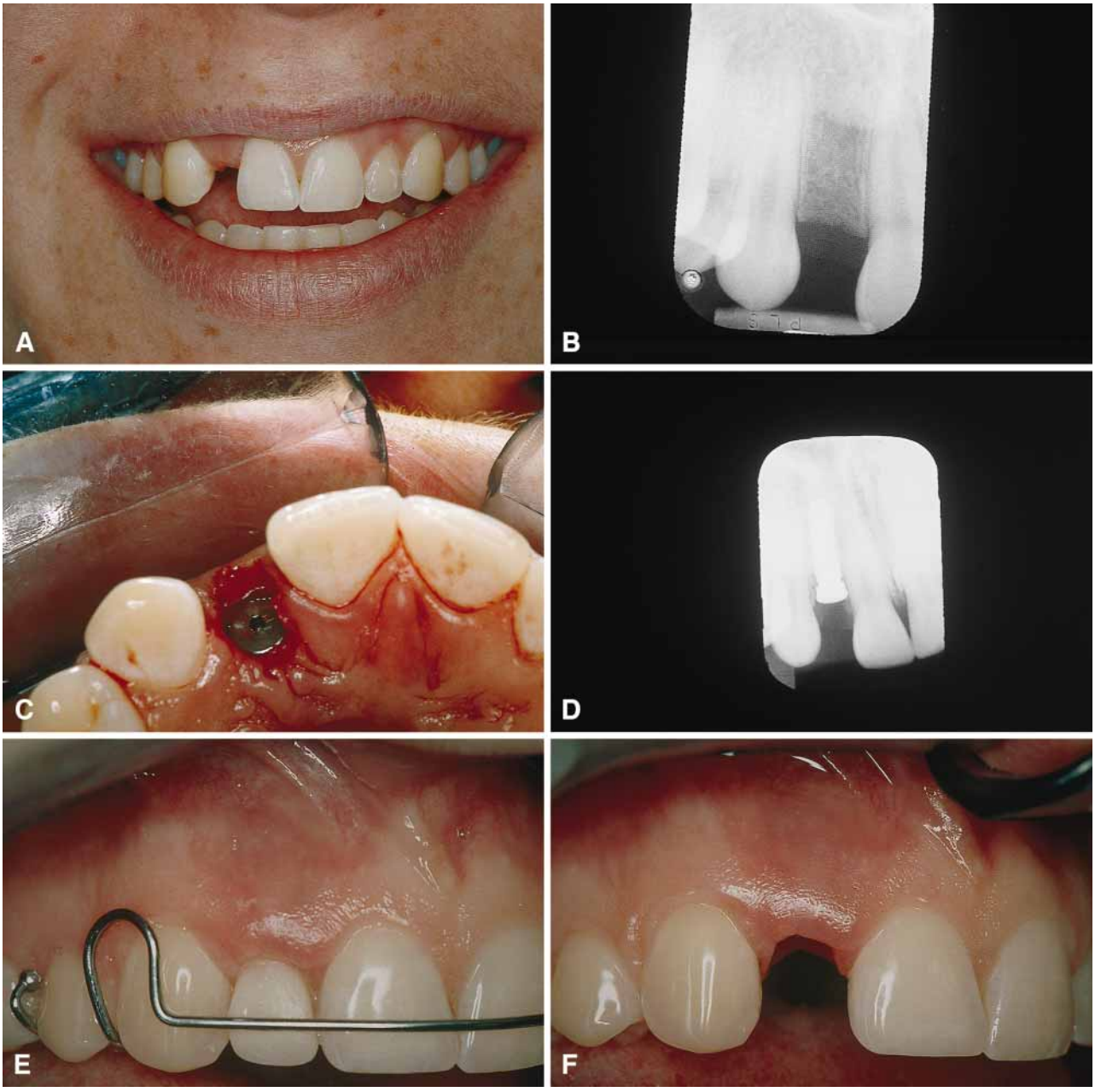


Fig. 3. A. Ideal position of the implant for a screw-retained restoration: the long axis of the implant body should exit at the cingulum of the tooth outline. **B.** In case of resorption of the osseous crest, the implant should be positioned in a more palatal orientation. A deeper housing of the implant platform is needed to provide adequate room for the emergence profile of the crown. **C.** Whenever the implant position is not deep enough, the prosthetic design should be modified by means of a ridge-lap design to compensate for the emergence profile of the crown.



rect the vertical bone height at the implant site. An edentulous area with extensive vertical loss of osseous structure may not be suitable for single-tooth aesthetic implant restoration.

Limitations in bone quantity in the mesiodistal dimension may be due to the root position of the adjacent teeth. Orthodontic movement should be used to change the root position providing the space for implant insertion. A reduced horizontal distance between the tooth and the neighboring implant may adversely affect the bone level at the tooth surface (32). A minimum of 1.5 mm of bone between the implant surface and the root surface should be present.

The bone volume at the implant site is measured on computed tomographic films taken with a radiographic template reproducing the proposed position of the final restoration. Periapical radiographs are used to evaluate the mesiodistal position of the roots adjacent to the implant site.

Implant placement into healed site

Several site classifications for single-tooth implant placement have been reported in the literature (14,

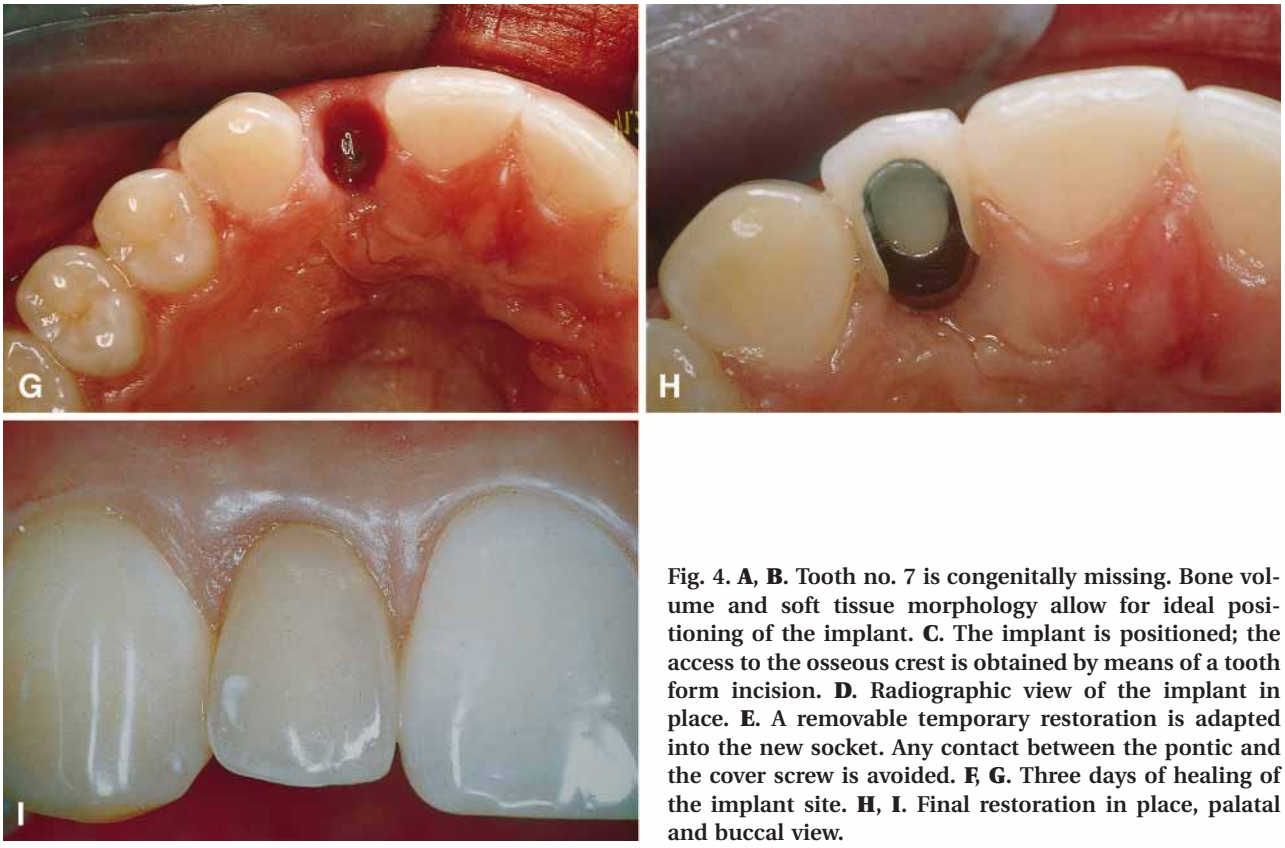


Fig. 4. A, B. Tooth no. 7 is congenitally missing. Bone volume and soft tissue morphology allow for ideal positioning of the implant. C. The implant is positioned; the access to the osseous crest is obtained by means of a tooth form incision. D. Radiographic view of the implant in place. E. A removable temporary restoration is adapted into the new socket. Any contact between the pontic and the cover screw is avoided. F, G. Three days of healing of the implant site. H, I. Final restoration in place, palatal and buccal view.

34). The classification in the anterior maxilla is based on bone volume and the soft tissue contour.

Type 1 healed site

The vertical bone volume is maintained; the thickness of the bone crest is ≥6 mm on the buccolingual dimension. The soft tissue morphology is in harmony with the present dentition (Fig. 2a).

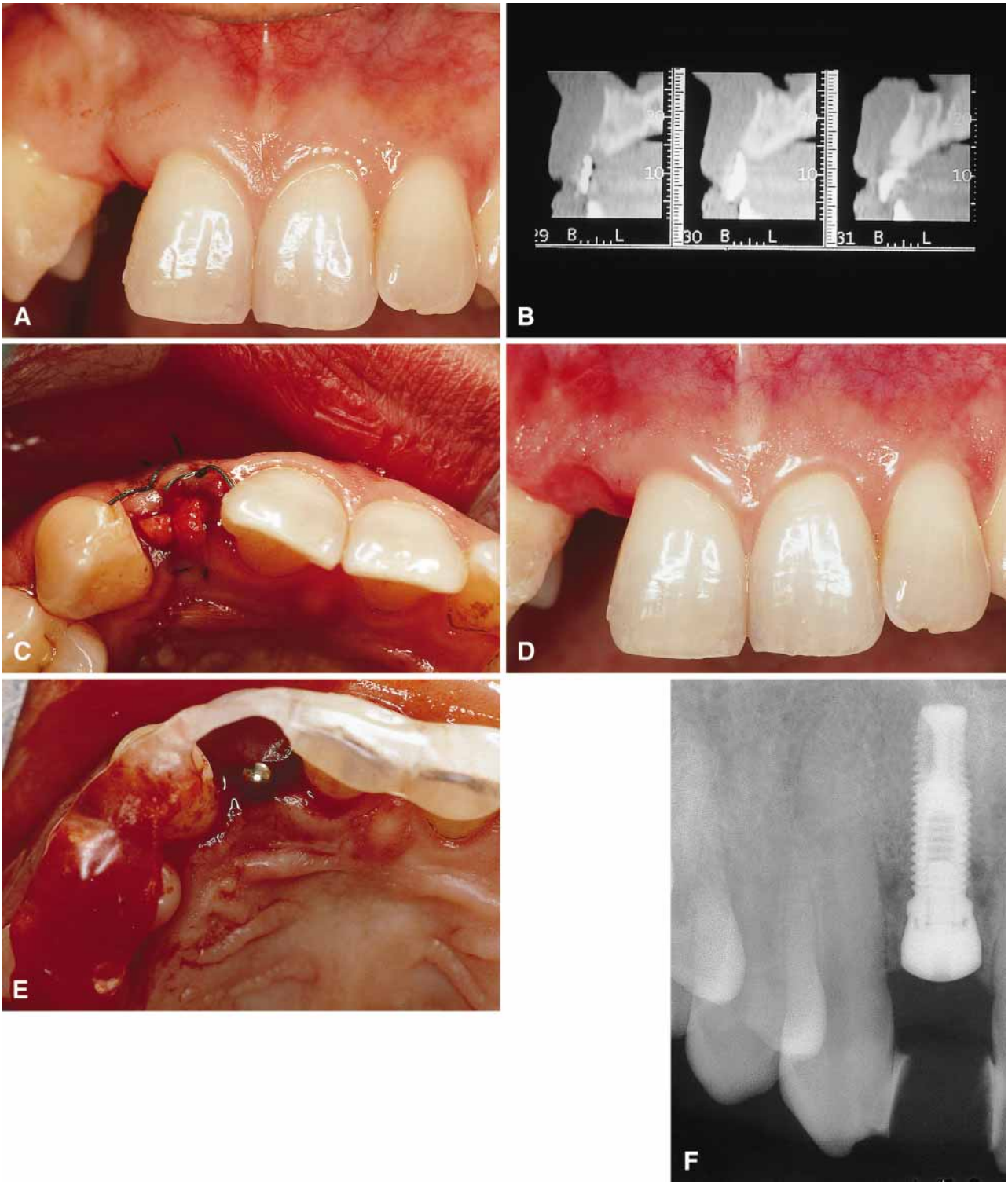
The implant can be placed in proper position. Since bone volume and soft tissue contour are optimal, no further treatments in addition to the implant placement are needed.

Different flap designs are proposed to gain access to the bone crest with minimal trauma to the soft tissue: envelope flap with crestal incision (14); palatal approach with minimal buccal flap reflection (11, 80); and pouch without flap elevation (8, 91).

The surgical guide dictates the position of the implant. The head of the implant is positioned at the bone crest about 3 mm apical to the level of the buccal soft tissue of the adjacent teeth (Fig. 2b). Care has to be taken to preserve 1 mm of bone thickness on the buccal wall of the osteotomy site to prevent bone dehiscence and detrimental sequelae to the soft tissue. The long axis of the implant body should be oriented according to the type of restoration planned and as far buccally as possible. For a screw-retained restoration, the projection of the long axis of the implant should exit at the cingulum of the tooth outline. If a cemented restoration is planned, the projection of the long axis of the implant should be at the incisal edge of the crown (Fig. 3).

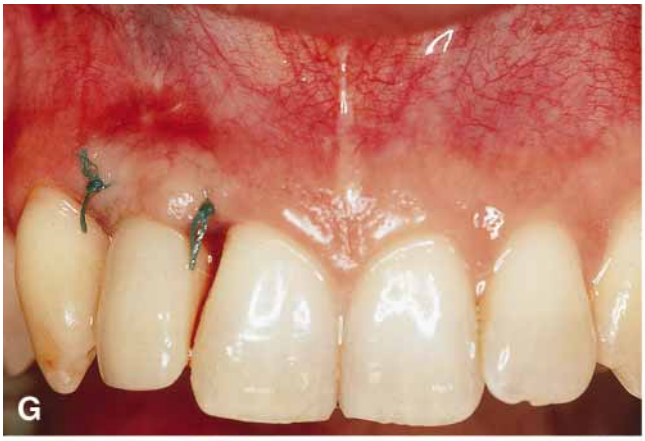
Once the implant is stabilized, the position is indexed using the surgical guide (42) and transferred to the cast. This allows fabrication of a customized provisional restoration that may be used at the implant uncovering (42). A cover screw (two-stage) or a healing abutment (one-stage) is positioned on the implant. The flap is sutured and a temporary restoration is placed at the edentulous area during the healing period.

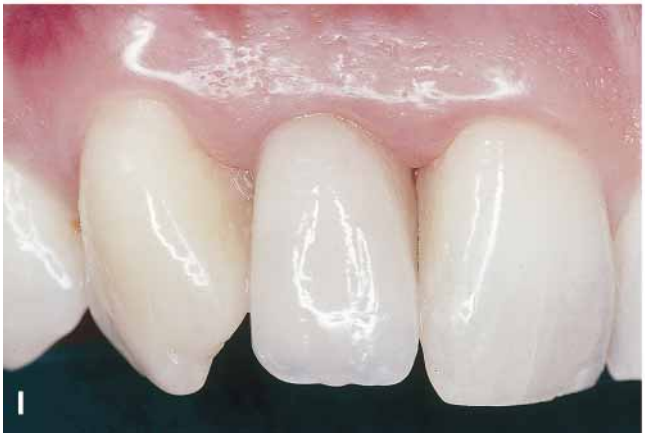
The use of the provisional restoration to improve the quality of the soft tissue at the implant-crown interface has been evaluated in the literature (24, 42, 49, 50, 69) (Fig. 2c). A more expedient restoration of the interproximal soft tissue by means of the temporary crown at the time of the implant uncovery has been compared to the use of the healing abutment alone (50). The immediate provisionalization has been proposed to provide maximal soft tissue support after immediate implant placement in aes-



thetic areas (113). Care must be taken to avoid any occlusal contact over the implant during the first 6 months after placement (113). A complete elimination of the load on an implant-supported restoration is not always possible, and the early loading may jeopardize the implant osseointegration. Although the immediate loading of single-tooth implant restoration has been recently evaluated, it cannot currently be considered for routine clinical use (31).

A modified protocol is proposed for an immediate adaptation of a temporary crown at the time of im-





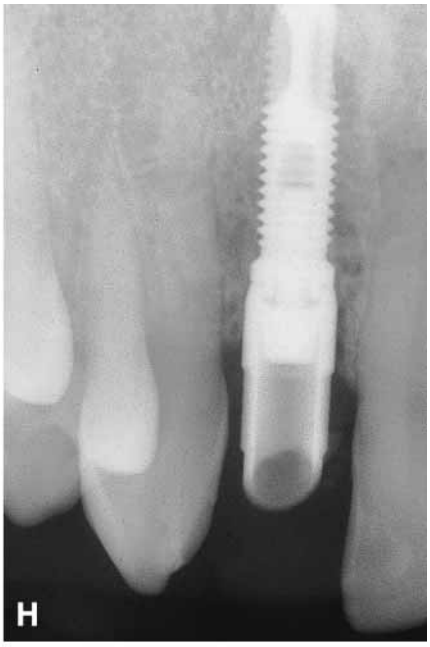


Fig. 5. A. Tooth site no. 7 represents a type 2 healed site. The vertical osseous and soft tissue dimension is preserved. A slight horizontal soft tissue collapse is present on the buccal aspect. B. The thickness of the osseous crest is >6 mm, as measured on the computed tomographic scan. C. A connective tissue graft is performed before the implant placement. D. The soft tissue defect is corrected. The implant is positioned according to the surgical guide. E. Radiographic view. To a palatal orientation of the implant body should correspond a deeper location of the implant platform (4–5) mm from the level of the soft tissue of the adjacent teeth. F. At the second-stage surgery, a temporary crown is adapted on the implant. G. Radiographic view of the temporary abutment connection. H. Final restoration.

plant placement without connecting the crown to the implant. The early provisionalization is used to improve the soft tissue morphology while avoiding early implant loading.

To access the osseous crest, a tooth form incision is suggested (8, 91) resulting in reduced soft tissue trauma and maximal preservation of the interproximal papilla (Fig. 4a–c). The bone morphology has to be visualized using computerized tomography and osseous sounding to avoid a dehiscence or fenestration during the drilling phase.

After the implant is positioned, a healing screw is secured on the implant and a removable or fixed temporary pontic (resin bonded to the adjacent teeth) is adapted into the new soft tissue socket in a way that the ideal soft tissue profile for the final restoration is obtained (Fig. 4e–g). The pontic surface must be polished and cold sterilized. To avoid any contact between the pontic and the implant, a 1- to 1.5-mm distance between the pontic and the top of the healing abutment is left to allow soft tissue healing over the implant screw. The healing process will lead to a thin epithelialized connective tissue barrier covering the healing screw and underlying the pontic surface. No sutures are necessary.

This protocol is indicated in cases of a thin scalloped periodontium with a long and thin papillae present at the time of the implant placement.

Type 2 healed site

The vertical osseous dimension of the site has not been altered. The thickness of the bone crest is ≥6 mm and associated with slight soft and hard tissue collapse in the buccolingual dimension (Fig. 5a, b).

Soft tissue augmentation may be necessary to re-

store the buccal soft tissue profile and develop the emergence of the peri-implant mucosa. Soft tissue plastic procedures can be performed before implant placement or at the time of second-stage surgery (Fig. 5c).

The bone volume available should allow the implant placement in pristine bone. However, the long axis of the implant should lie in a more palatal position since the buccal side of the crest has been resorbed. A more palatal position of the implant body should correspond to a deeper housing of the implant head, about 4–5 mm from the buccal soft tissue of the adjacent teeth. The position of the head should permit enough transition room to restore the emergence profile of the crown (Fig. 5d, e).

Type 3 healed site

The vertical dimension of the site has not been altered but the buccal bone loss does not allow for implant placement in a correct position. The thickness of the bone at the crest is ≤5 mm and >3 mm. To allow the implant proper positioning, adjunctive treatments to augment the osseous crest are needed. Soft tissue plastic procedures may also be necessary to restore the soft tissue contour.

The augmentation of the osseous ridge can be achieved using procedures that modify the morphology of the existing bone such as split-crest techniques (28, 94, 98), ridge expansion with osteotomes (102, 103) or osseous grafts.

The split-crest technique consists in separating the buccal and lingual osseous plate using chisels or knives (28, 94, 98). After the separation of the crest, a "green-stick" fracture is created displacing the two osseous plates buccally and lingually. The implant is positioned whithin the fracture line, stabilized into the apical bone and supported buccally and lingually by the displaced osseous plates. The proximal surfaces of the implant are not in contact with bone at the time of placement. Barrier membranes have been used to enhance bone formation at the proximal surface of the implant (98). However, newly formed bone in contact with the proximal implant surface has been observed without the use of barrier membranes (95).

The success rate of the split-crest technique for the single-tooth implant placement is reported to be between 88% to 93% over an observation period of 4–5 years (28, 94). A reduction in marginal bone height has been observed on the tooth surface at the implant–tooth interface (28). Interproximal bone loss may lead to loss of the interdental papilla and consequent aesthetic failure of the procedure.

A buccal flap design extended to the adjacent teeth with vertical releasing incisions is suggested to gain access to the osseous crest. A partial thickness dissection provides blood supply to the osseous plate, reducing the possibility of bone resorption (94). The soft tissue management becomes critical in the presence of a thin and scalloped periodontium and high smile line.

The osteotome technique has been described by Summers (102, 103). The osteotomy site is prepared using a series of cylindrical instruments (osteotomes) with increasing diameter, inserted into the osseous crest by pressure or by gentle malleting. When the desired diameter of the osteotomy site is reached, the implant is placed. Since the use of drills is limited or avoided, the bone volume is preserved and the bony housing of the implant is obtained by means of compression of the cancellous bone and expansion of the cortical plates. The preparation of the osteotomy site using osteotomes in the presence of soft bone may provide increased density of the bone in contact with the implant surface (102, 103). When only cortical bone is present, there is risk of fracture of the cortical plates.

A minimal flap design is needed to gain access to the osseous crest. The elevation of the buccal flap can be avoided. The bone morphology has to be visualized by means of computerized tomography or hard tissue mapping.

Since the original description, no study has been reported on the ridge expansion technique, and all indications presented are based on anecdotal data and clinical experience of the authors.

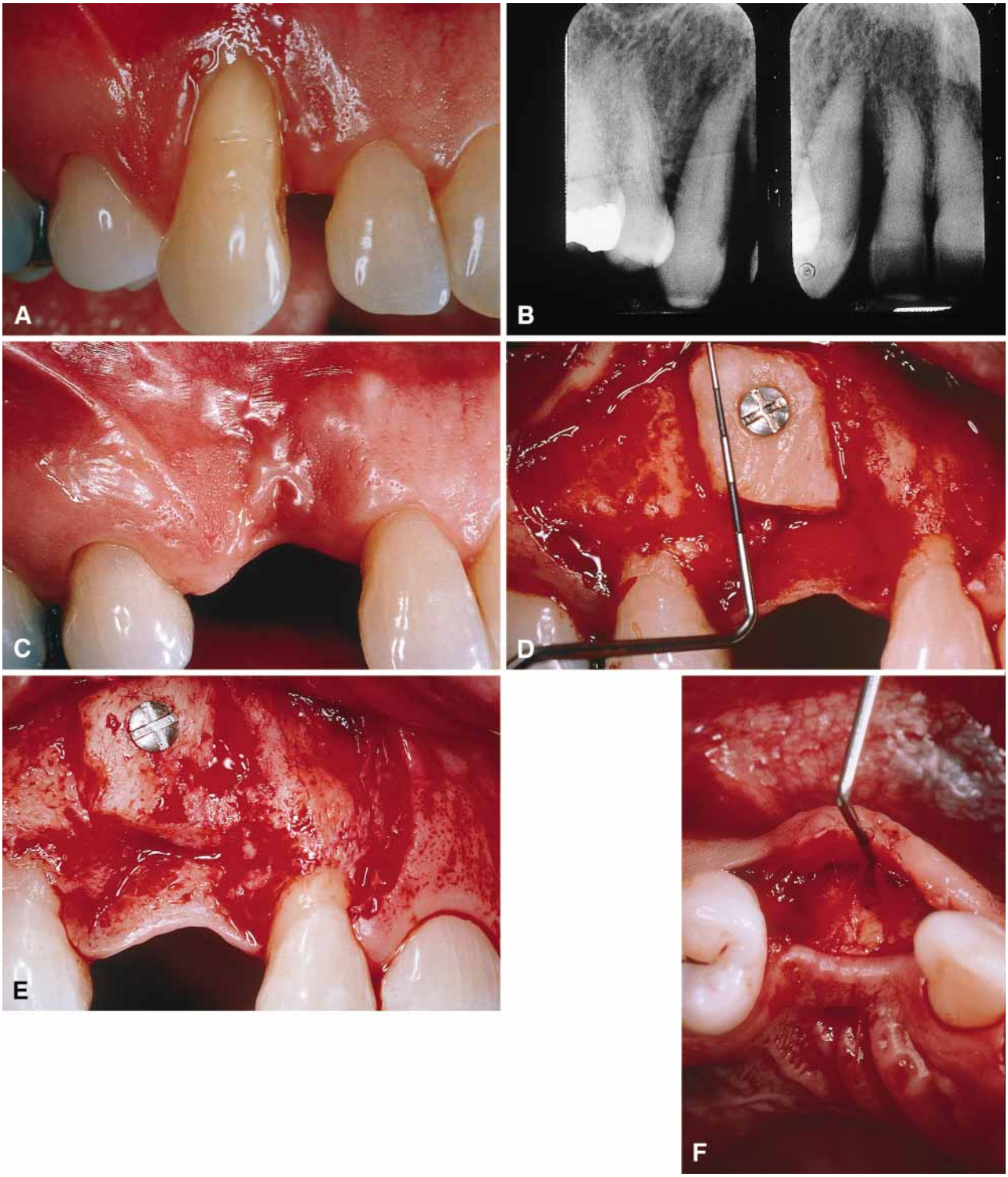
The use of guided bone regeneration by means of barrier membrane, alone or in combination with grafting material, has been widely applied for the treatment of peri-implant defects. For extensive review of the biological principle of guided bone regeneration, see Hämmerle & Karring (40). The studies presented in the literature show that implant survival rates using the barrier membrane technique are similar to the success rate of implants placed in pristine bone (Table 2). However, the success criteria of the implant placed with the use of barrier membrane has never addressed the final outcome in terms of soft tissue morphology, which is of particular concern in aesthetic areas.

One of the most common complications using nonresorbable barrier membranes (expanded polytetrafluoroethylene) is the early exposure of the device and subsequent infection (21, 74, 97, 109). The

Table 2. Guided bone regeneration with barrier membranes with or without grafting material at implant placement. Clinical studies

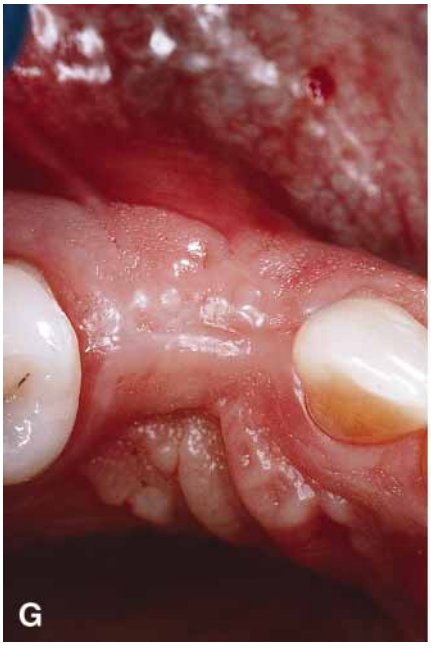
Author	Implant	*n*	Membrane	Defect type	Grafting material	Membrane exposure %	Implant success rate %
Dahlin et al. (26)	Brånemark	14	Gore-Tex Augmentation Material	Dehiscence Fenestration			100
Jovanovic et al. (52)	Brånemark	17	Gore-Text Augmentation Material	Dehiscence	Autogenous graft	17	100
Simion et al. (98)	Brånemark	5	Gore-Text Augmentation Material	Ridge		25	100
Andersson et al. (4)	Brånemark	11	Gore-Text Augmentation Material	Dehiscence Fenestration	NA	45	91
Mellonig & Triplett (67)	Brånemark	66	Gore-Tex Augmentation Material	Dehiscence Fenestration Others	Demineralized freeze-dried bone	53	NA
Rominger & Triplett (85)	NA	110	Gore-Tex Augmentation Material	Dehiscence Fenestration others	Freeze-dried bone	28	0.9
Dahlin et al. (27)	Brånemark	55	Gore-Tex Augmentation Material	Dehiscence Fenestration		11	84.7 maxilla 95 mandible
Jovanovic & Nevins (51)	Brånemark	7	Titanium-reinforced Gore-Tex Augmentation Material	Dehiscence Fenestration	Autogenous	0	100
Mattout & Nowzari (64)	Brånemark	34	Gore-Tex Augmentation Material	Dehiscence Fenestration	Demineralized freeze-dried bone		100
Nowzari & Slots (74)	Brånemark	17	Gore-Tex Augmentation Material	Dehiscence Extraction defect		47	100
Mayfield et al. (65)	Brånemark	17	PLA/PGA	Dehiscence Fenestration		0	100
Simion et al. (99)	Brånemark	9 9	Gore-Tex Augmentation Material PLA/PGA	Dehiscence Fenestration	Autogenous bone	0 0	100
Lorenzoni et al. (61)	Frialit	46 45 38	Gore-Tex Augmentation Material Titanium-reinforced Gore-Tex Augmentation Material Biofix	Dehiscence Fenestration	Autogenous bone Bio-Oss	22 47 50	100

Brånemark: Nobel Biocare AB, Göteborg, Sweden
Biofix-Biocon Ltd, Tampere, Finland
Bio-Oss Geistlich Sohne AG, Wohlhusen, Switzerland
Frialit: Friatec AG, Mannheim, Germany
Gore-Tex Augmentation Material: W.L. Gore and Associates, Flagstaff, AZ
Titanium-reinforced Gore-Tex augmentation material: W.L. Gore and Associates
PLA/PGA Resolut: W.L. Gore and Associates



bacterial colonization of the membrane may lead to abscess, soft tissue loss and bone loss resulting in irreversible aesthetic failure. The prevalence of surgical complications with barrier membranes is reduced when resorbable devices are utilized. However, the volume of bone repair is diminished when resorbable barrier membranes are used compared with nonresorbable membrane (61, 100).

The application of the barrier membranes requires wide access to the osseous surface. Extended buccal and palatal flaps are required. Vertical releasing incisions are utilized to mobilize the flap and reduce



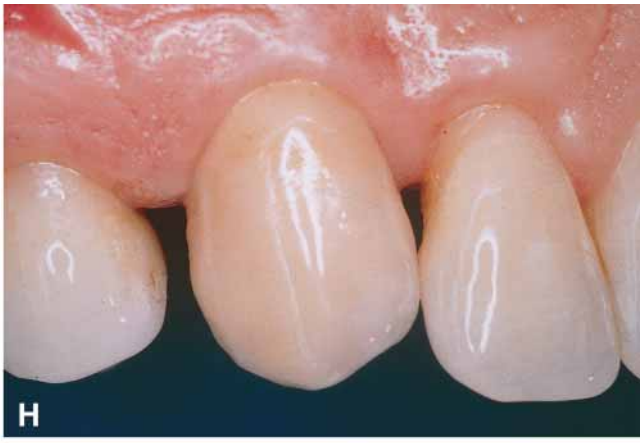


Fig. 6. A, B. Tooth no. 5 presents extensive bone loss and soft tissue loss due to periodontal infection and is planned for extraction. C. An osseous and soft tissue defect resulted from the tooth extraction. D. A block bone graft is harvested from the chin and secured on the recipient site by means of a titanium screw. E. Healing of the osseous graft after 3 months. F. A connective tissue graft is used to correct the residual soft tissue defect. G. The implant site has been reconstructed for the implant placement. H. Final restoration in place.

tension. Soft tissue management is critical to reduce the risk of tissue collapse or membrane exposure. The use of guided tissue regeneration with barrier membranes may not be indicated in the presence of a thin periodontium and a high smile line.

Type 4 healed site

The vertical dimension of the site has not been altered but buccal bone resorption does not allow for implant placement. The thickness of the bone crest is <3 mm, associated with significant soft tissue collapse.

A staged approach is suggested. The restoration of the implant site should be performed using techniques for augmentation of the osseous ridge combined with soft tissue plastic procedures. The implant should first be placed after the site is restored (Fig. 6).

Type 5 healed site

The vertical dimension of the site has been altered and the buccal bone resorption does not allow for implant placement. The thickness of the bone crest is <3 mm, associated with significant soft tissue collapse.

A staged approach is suggested. Several surgical techniques are described for augmenting the vertical dimension of the implant site. Bone grafts (J-graft), osseous distraction (15, 33, 75, 76), segmental osteotomy (44, 63) and guided bone regeneration (101).

After the implant site is restored properly with respect to both hard and soft tissue, the fixture can be placed in ideal position.

Immediate implant placement

Treatment rationale

A period of 4 to 12 months between tooth extraction and implant placement is the proposed protocol for implant insertion (18).

However, after tooth extraction, advanced resorption may produce a tapering alveolar crest in which the majority of the hard and soft tissue defect is not surrounded by osseous walls. Furthermore, the long-term interruption of the functional stimulation related to late implantation may lead to a reduction of osseous trabecular pattern and capillary density (23). The most extensive resorption takes place during the first year following extraction and reaches the maximum rate over the first 6 months, particularly in the saggittal plane in the mandible, and more buccal and horizontally directed in the maxilla (22, 104).

To reduce the effect of bone remodeling at the extraction site, the immediate placement of implants into fresh extraction sockets has been proposed (58). Several case reports and clinical studies have shown a survival rate of immediately placed implants ranging between 93.9% to 100%, comparable to the success rate of implants placed into healed sites (Table 3).

Table 3. Immediate implant placement. Clinical studies and case series (chronological order)

Authors	Implant type	*n*	Graft	Membrane	Exposure	Follow-up	Failure rate %
Brose et al. (19)	Titanium alloy	13				1 year	0
Brose et al. (20)	Titanium alloy	12				18 months	0
Quayle et al. (84)	Tübingen	100				2 years	12
Ashman (5)	Steri-oss	22	HTR			6–24 months	6
Tolman & Keller (108)	Brånemark	303				1–6 years	1
Krump & Barnett (55)	Brånemark	41				1–4 years	7
Yukna (114)	Calcitek	14	Calcitite		50%	8–24 months	0
Block & Kent (16)	Calcitek	62	Hydroxyapatite, demineralized bone particles		19%	4 years	0
Werbitt & Goldberg (112)	Brånemark	6	Demineralized freeze-dried bone	Expanded polytetrafluoroethylene Gore-Tex	25%	6–8 months	0
Schultz (93)	ITI	6	Demineralized freeze-dried bone	Expanded polytetrafluoroethylene Gore-Tex	83%	6 months	0
Gelb (35)	Brånemark	50	Demineralized freeze-dried bone	Expanded polytetrafluoroethylene Gore-Tex	46%	1–3 years	2
Becker & Becker (11)	Brånemark	49		Expanded polytetrafluoroethylene Gore-Tex	41%	1 year	6
Becker & Becker (11)	Brånemark	50	Autogenous bone			1 year	0
Gher et al. (36)	Calcitek	43	Demineralized freeze-dried bone	Expanded polytetrafluoroethylene Gore-Tex	63%	6 months	0
Lang et al. (57)	ITI	21		Expanded polytetrafluoroethylene Gore-Tex		30 months	0
Simion et al. (97)	Dentsply	10		Expanded polytetrafluoroethylene Gore-Tex	10%	6 months	0
Augthun et al. (6)	Brånemark	10		Expanded polytetrafluoroethylene Gore-Tex	67%	6 months	20
Brägger et al. (17)	ITI	48		Expanded polytetrafluoroethylene Gore-Tex		1 year	0
Rosenquist & Grenthe (86)	Brånemark	109				30 months	6.4
Schwartz-Arad & Chaushu (92)	Dentsply	95	Autogenous bone			4–7 years	5.3
Hämmerle et al. (39)	ITI	11		Expanded polytetrafluoroethylene Gore-Tex	20%	5 months	0
Becker et al. (10)	Brånemark	134				4–5 years	6.7
Schwartz-Arad & Chaushu (91)	Brånemark Core-vent Calcitek	7 1 1	Autogenous bone			6 months	0
Wohrle (113)	Steri-Oss	14				6–36 months	0

Brånemark: Nobel Biocare AB, Göteborg, Sweden. Calcitek: Carlsbad, CA. Dentsply Implant Division, Encino, CA. Gore-Tex: W.L. Gore and Associates, Flagstaff, AZ. HTR: HTR Science, Norwalk, CT. ITI: The Straumann Co., Cambridge, MA. Steri-Oss: Steri-Oss Inc., Yorba Linda, CA. Tübingen: Frialit, Friedrichsfeld GmbH, Mannheim, Germany.

Advantages of immediate implant placement

Reduced treatment time. The restorative procedures can start as early as 4 to 6 months after tooth extraction.

Hard and soft tissue preservation. Bone volume and soft tissue support are preserved during the remodeling process (9).

Indications

Indications include a failing tooth due to trauma without bone loss, endodontic lesion, root fracture, extensive caries; adequate bone support for implant stabilization; and intact soft tissue morphology for aesthetics.

Contraindications

Contraindications include active infection: fistulous track and suppuration; an extensive osseous defect, preventing the insertion of the implant in an optimal position or the achievement of implant stability; and extensive soft tissue defect so that an aesthetic outcome cannot be anticipated.

When the implant site is not suitable for immediate placement at the time of tooth extraction because of active infection, a waiting period for socket healing is necessary. To avoid bone resorption, the early-delayed placement procedure has been proposed (37, 72, 77). A period of 6–8 weeks after tooth extraction allows the healing of the soft tissue and the resolution of associated infections (72). The success rate for the delayed-immediate implant placement ranges between 92% and 95% (37, 72).

Immediate implant placement sites

Not all extraction sites allow for the immediate implant placement. Several clinical classifications have been proposed for site selection and appropriate surgical procedures (12, 35, 88).

Determinants to be considered for the surgical treatment planning of an implant placed into an extraction site in aesthetic areas include: 1) the soft tissue contour (interproximal papilla and buccal soft tissue level) and 2) The bone morphology (the thickness of the palatal wall of the socket detected by computed tomography).

Type 1 immediate implant site

The soft tissue contour follows an ideal course in harmony with the present dentition. The palatal wall of the socket measures >3 mm in the buccolingual dimension at a depth of 3–5 mm from the soft tissue level of the adjacent teeth (Fig. 7). The implant can be placed at the time of extraction regardless of the morphology of the buccal wall of the socket.

No buccal flap is raised (Fig. 7a). A 3-mm-deep palatal scalloped incision is performed at the extraction site and extended to lateral teeth while gradually reducing the depth to 2 mm and 1 mm. Palatal scalloping eliminates inflamed coronal soft tissue, a major source of inflammatory cells and cytokines, and provides access for precise palatal osteotomy. A thin and wide elevator with a palatal approach is used for tooth extraction. Buccal fulcrum should be avoided. Forceps may be used only for the final phase of the extraction when the tooth can be rotated out easily. After degranulation of the extraction site, the osseous anatomy is re-evaluated by sounding. Osteotomy is initiated on the palatal wall of the extraction site 3–5 mm apical to the buccal soft tissue contour. A 2-mm round bur under copious irrigation is used with the surgical guide for optimal mesiodistal positioning. At this location a horizontal osteotomy directed toward the palatal cortical plate is performed. While horizontal osteotomy does not penetrate the palatal cortical plate, it provides access to maxillary spongious bone.

A 1.5-mm tapered osteotome is placed into the cut and malleted with copious irrigation to initiate the expansion or the splitting of the palatal crest. Larger diameter osteotomes are gradually malleted palatally in order to place the implant in an optimal buccopalatal position (Fig. 7b). Horizontal expansion of the thin palatal wall of the extraction site is achieved by pushing buccally and laterally the ridge. To increase the availability of osteogenic cells and improve implant integration, the palatal bone must be prepared gradually. The osteotomy site is enlarged to improve its adaptation to the implant and minimize the formation of dead spaces between the implant and the recipient site (Fig. 7c). The implant is placed into a sound bony housing obtained on the palatal wall of the extraction site, away from the buccal wall of the socket and the socket itself (Fig. 7d, e). The head of the implant should lie 0 to 3 mm from the osseous crest to a maximal depth of 5 mm from the buccal soft tissue level measured on the adjacent teeth (Fig. 7d, e). A healing screw or abutment is secured on the

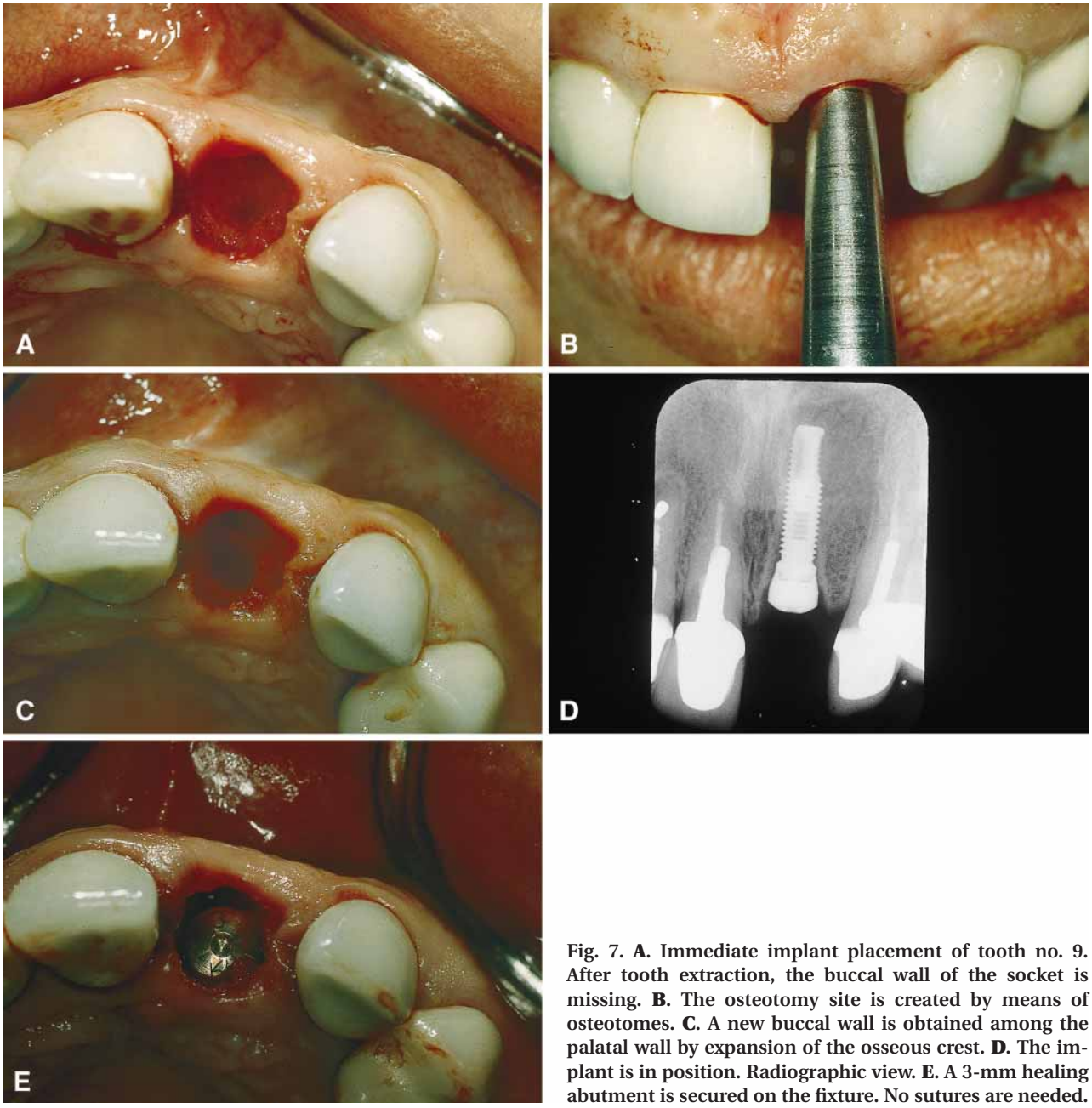


Fig. 7. A. Immediate implant placement of tooth no. 9. After tooth extraction, the buccal wall of the socket is missing. B. The osteotomy site is created by means of osteotomes. C. A new buccal wall is obtained among the palatal wall by expansion of the osseous crest. D. The implant is in position. Radiographic view. E. A 3-mm healing abutment is secured on the fixture. No sutures are needed.

implant and the palatal incision is sutured if needed.

No primary soft tissue closure is attempted. Flap closure over the implant has been regarded as a critical factor for the success of immediate implant placement. Several flap designs and techniques for soft tissue management are described to obtain soft tissue primary closure (70, 71, 87). However, no differences in success rates are reported between a one-stage (nonsubmerged) versus a two-stage (submerged) implant system, used for immediate placement (17, 36, 39, 91, 113).

The type of provisional prosthesis used during the healing period is critical to optimal healing. The design of the provisional restoration should minimize postsurgical irritation and pressure on the soft tissue.

Immediate installation of a provisional restoration, soft tissue adaptation to the provisional and no need for suturing positively influence the soft tissue healing (113). A resin-bonded restoration or bonding the coronal portion of the extracted tooth are effective means of preserving or re-creating interdental papillae (49, 50, 113).

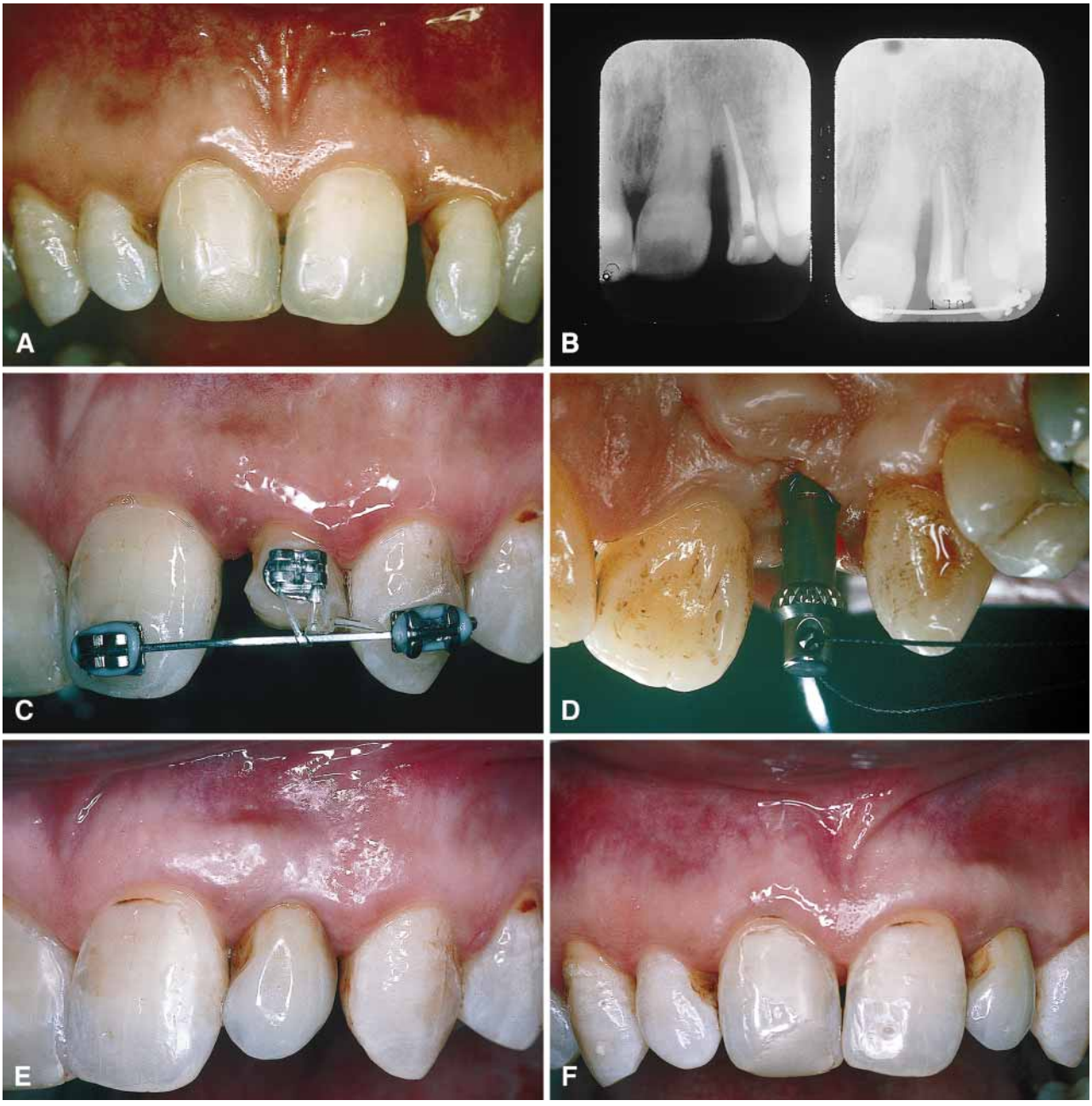


Fig. 8. A, B. Tooth no. 10 presents extensive bone loss due to periodontal infection. C. Orthodontic forced eruption of the tooth is applied to correct the osseous and soft tissue defect. D. The implant is placed at the time of tooth extraction; no flap is raised. E, F. Final restoration.

Type 2 immediate implant site

A type 2 immediate implant site entails a soft tissue dehiscence or partial collapse of the interproximal soft tissue. The buccal wall is partially resorbed. The palatal wall of the socket measures >3 mm in the buccolingual dimension at a depth of >5 mm from the soft tissue level.

The soft tissue defect can be corrected and the osseous crest position modified using orthodontic forced eruption (46, 88). By stretching the gingival fiber apparatus during the forced eruptive movement, tension is imparted to the entire osseous housing of the tooth, stimulating osseous apposition at the alveolar crest, which has the tendency to maintain a constant relationship with the cemento-enamel junction. The forced eruption increases the zone of attached gingiva and the interproximal soft tissue level as well, as the mucogingival junction remains stable when the gingival margin migrates co-

ronally (Fig. 8). Orthodontic forced eruption is not indicated in the presence of active periapical lesions and other types of infections.

When the osseous crest reaches the desired position, or the soft tissue profile is corrected, the tooth is extracted and the implant placed according to the technique previously described for the type I immediate implant site.

To correct both hard and soft tissue defects at the extraction site, barrier membrane and/or grafting materials have been proposed (Table 2). The use of a barrier membrane with the immediate placement of the implant may lead to complications related to membrane exposure, such as soft and hard tissue dehiscence or loss of the implant. Membrane exposure with immediate implant placement ranges between 0 and 83% (Table 3).

Type 3 immediate implant site

A type 3 immediate implant site entails deep soft tissue collapse. The buccal wall is totally resorbed or there may be extended periapical or periodontal lesions. The palatal wall measures <3 mm in thickness. Implant placement requires a staged approach. Extraction of the tooth followed by bone-grafting procedure as well as soft tissue plastic procedures. Hard and soft tissue grafting procedures should be performed before implant placement (Fig. 6).

Conclusions

Replacement of the anterior tooth with conventional fixed partial denture or resin-bonded restorations achieves highly aesthetic results. When single-tooth implant restorations are considered in restoring aesthetic areas, the same level of aesthetic outcome should be provided.

Prosthodontic treatment planning is essential in determining whether the single-tooth implant restoration would satisfy the requirements of occlusion, aesthetics, phonetics and preservation of tooth structure. Surgical treatment planning should lead to decisions about the positioning of the implant and hard and soft tissue management to obtain proper housing of the fixture and the ideal soft tissue environment surrounding the restoration.

Patient expectation, smile line, soft and hard tissue morphology should guide the treatment pathway toward a predictable aesthetic result.

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References

1. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Surg 1990: **5**: 347–359.
2. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15 year study of osseointegrated implants in the treatment of edentulous jaws. Int J Oral Surg 1981: **10**: 387–416.
3. Andersson B, Odman P, Lindvall AM, Lithner B. Single-tooth restorations supported by osseointegrated implants: results and experiences from a prospective study after 2 to 3 years. Int J Oral Maxillofac Implants 1995: **10**: 702–711.
4. Andersson B, Odman P, Widmark G, Waas A. Anterior tooth replacement with implants in patients with a narrow alveolar ridge form. A clinical study using guided tissue regeneration. Clin Oral Implants Res 1993: **4**: 90–98.
5. Ashman A. An immediate tooth root replacement: an implant cylinder and synthetic bone combination. J Oral Implantol 1990: **16**: 28–38.
6. Augthun M, Yildirim M, Spiekermann H, Biesterfeld S. Healing of bone defects in combination with immediate implants using the membrane technique. Int J Oral Maxillofac Implants 1995: **10**: 421–428.
7. Avivi-Arber L, Zarb GA. Clinical effectiveness of implant-supported single-tooth replacement: the Toronto Study. Int J Oral Maxillofac Implants 1996: **11**: 311–321.
8. Bader Al-Ansari H, Morris RR. Placement of dental implants without flap surgery: a clinical report. Int J Oral Maxillofac Implants 1998: **13**: 861–865.
9. Barzilay I, Graser GN, Iranpour B, Natiella JR. Immediate implantation of a pure titanium implant into an extraction socket: report of a pilot procedure. Int J Oral Maxillofac Implants 1991: **6**: 277–284.
10. Becker BE, Becker W, Ricci A, Geurs N. A prospective clinical trial of endosseous screw-shaped implants placed at the time of tooth extraction without augmentation. J Periodontol 1998: **69**: 920–926.
11. Becker W, Becker BE. Flap designs for minimization of recession adjacent to maxillary anterior implant sites: a clinical study. Int J Oral Maxillofac Implants 1996: **11**: 46–54.
12. Becker W, Dahlin C, Becker BE, Lekholm U, van Steenberghe D, Higuchi K, Kultje C. The use of e-PTFE barrier membranes for bone promotion around titanium implants placed into extraction sockets: a prospective multicenter study. Int J Oral Maxillofac Implants 1994: **9**: 31–40.

13. Becker W, Ochsenbein C, Tibbets L, Becker BE. Alveolar bone anatomic profiles as measured from dry skulls: clinical ramification. J Clin Periodontol 1997: **24**: 727–731.
14. Belser UC, Buser D, Hess D, Schmid B, Bernard JP, Lang NP. Aesthetic implant restorations in partially edentulous patients – a critical appraisal. Periodontol 2000 1998: **17**: 132–150.
15. Block MS, Almerico B, Crawford C, Gardiner D, Chang A. Bone response to functioning implants in dog mandibular alveolar ridges augmented with distraction osteogenesis. Int J Oral Maxillofac Implants 1998: **13**: 342–351.
16. Block MS, Kent JN. Placement of endosseous implant into tooth extraction sites. J Oral Maxillofac Surg 1991: **49**: 1269–1276.
17. Brägger U, Hämmerle CH, Lang NP. Immediate transmucosal implants using the principle of guided tissue regeneration. II. A cross-sectional study comparing the clinical outcome 1 year after immediate to standard implant placement. Clin Oral Implants Res 1996: **7**: 268–276.
18. Brånemark PI, Zarb GA, Albrektsson T. Tissue integrated prostheses osseointegration in clinical dentistry. Chicago: Quintessence Publications, 1987.
19. Brose M, Michney RA, Reiger M, Woelfel J. Evaluation of titanium alloy endosseous dental implant in humans. J Dent Res 1988: **67**(spec issue): 377 (abstr 2034).
20. Brose MO, Michney RA, Reiger MR, Tanquist RA. Titanium alloy implants for fixed and removable prostheses. J Dent Res 1989: **68**(spec issue): 377 (abstr 1562).
21. Buser D, Brägger U, Lang NP, Nyman S. Regeneration and enlargement of jaw bone using guided tissue regeneration. Clin Oral Implants Res 1990: **1**: 22–32.
22. Carlsson GE, Bergman B, Hedegard B. Changes in contour of the maxillary alveolar process under immediate dentures. A longitudinal clinical and x-ray cephalometric study covering 5 years. Acta Odontol Scand 1967: **25**: 45–75.
23. Carlsson GE, Thilander H, Hedegard B. Histologic changes in the upper alveolar process after extractions with or without insertion of an immediate full denture. Acta Odontol Scand 1967: **25**: 21–43.
24. Chee WW, Donovan T. Use of provisional restorations to enhance soft-tissue contours for implant restorations. Compendium Contin Educ Dent 1998: **19**: 481–486, 488–489.
25. Chee WW, Nowzari H, Kaneko L. Esthetic replacement of the anterior tooth with an implant-supported restoration. J Calif Dent Assoc 1997: **25**: 860–865.
26. Dahlin C, Andersson L, Linde A. Bone augmentation at fenestrated implants by an osteopromotive membrane technique. A controlled clinical study. Clin Oral Implants Res 1991: **2**: 159–165.
27. Dahlin C, Lekholm U, Becker W, Becker B, Higuchi K, Callens A, van Steenberghe D. Treatment of fenestration and dehiscence bone defects around oral implants using the guided tissue regeneration technique: a prospective multicenter study. Int J Oral Maxillofac Implants 1995: **10**: 312–318.
28. de Wijs FL, Cune MS. Immediate labial contour restoration for improved esthetics: a radiographic study on bone splitting in anterior single-tooth replacement. Int J Oral Maxillofac Implants 1997: **12**: 686–696.
29. Ekfeldt A, Carlsson GE, Borjesson G. Clinical evaluation of single-tooth restorations supported by osseointegrated implants: a retrospective study. Int J Oral Maxillofac Implants 1994: **9**: 179–183.
30. Engquist B, Nilson H, Åstrand P. Single-tooth replacement by osseointegrated Brånemark implants. A retrospective study of 82 implants. Clin Oral Implants Res 1995: **6**: 238–245.
31. Ericsson I, Nilson H, Lindh T, Nilner K, Randaw K. Immediate functional loading of Brånemark single tooth implants. An 18 months clinical pilot follow-up study. Clin Oral Implants Res 2000: **11**: 26–33.
32. Esposito M, Ekestubbe A, Grondahl K. Radiological evaluation of marginal bone loss at tooth surfaces facing single Brånemark implants. Clin Oral Implants Res 1993: **4**: 151–157.
33. Gaggl A, Schultes G, Karcher H. Distraction implants: a new operative technique for alveolar ridge augmentation. J Craniomaxillofac Surg 1999: **27**: 214–221.
34. Garber D, Belser U. Restoration-driven implant placement with restoration-generated site development. Compendium Contin Educ Dent 1995: **16**: 796–804.
35. Gelb DA. Immediate implant surgery: three-year retrospective evaluation of 50 consecutive cases. Int J Oral Maxillofac Implants 1993: **8**: 388–399.
36. Gher ME, Quintero G, Assad D, Monaco E, Richardson AC. Bone grafting and guided bone regeneration for immediate dental implants in humans. J Periodontol 1994: **65**: 881–891.
37. Grunder U, Polizzi G, Goene R, Hatano N, Henry P, Jackson WJ, Kawamura K, Kohler S, Renouard F, Rosenberg R, Triplett G, Werbitt M, Lithner B. A 3-year prospective multicenter follow-up report on the immediate and delayed-immediate placement of implants. Int J Oral Maxillofac Implants 1999: **14**: 210–216.
38. Haas R, Mensdorff-Pouilly N, Mailath G, Watzek G. Brånemark single tooth implants: a preliminary report of 76 implants. J Prosthet Dent 1995: **73**: 274–279.
39. Hämmerle CH, Brägger U, Schmid B, Lang NP. Successful bone formation at immediate transmucosal implants: a clinical report. Int J Oral Maxillofac Implants 1998: **13**: 522–530.
40. Hämmerle CH, Karring T. Guided bone regeneration at oral implant sites. Periodontol 2000 1998: **17**: 151–175.
41. Henry PJ, Laney WR, Jemt T, Harris D, Krogh PH, Polizzi G, Zarb GA, Herrmann Henry PJ, Rosenberg IR, Bills IG, Chan RW, Cohen AC, Halliday KGI. 3-year follow-up study on single implant treatment. multicenter study. Int J Oral Maxillofac Implants 1996: **11**: 450–455.
42. Hochwald DA. Surgical template impression during stage I surgery for fabrication of a provisional restoration to be placed at stage II surgery. J Prosthet Dent 1991: **66**: 796–798.
43. Ingber JS. Forced eruption: alteration of soft tissue cosmetic deformities. Int J Periodontics Restorative Dent 1989: **9**: 416–425.
44. Itkin AB, Riker K, McKay K, Zweig BE. Posterior segmental osteotomy with simultaneous endosseous implant placement to facilitate fixed reconstruction. J Oral Implantol 1990: **16**: 116–120.
45. Jansen CE, Weisgold A. Presurgical treatment planning for the anterior single-tooth implant restoration. Compendium Contin Educ Dent 1995: **16**: 746–764.
46. Jemt T, Laney WR, Harris D, Henry PJ, Krogh PH Jr, Polizzi G, Zarb GA, Herrmann I. Osseointegrated implants for single tooth replacement: a 1-year report from a multicenter prospective study. Int J Oral Maxillofac Implants 1991: **6**: 29–36.

47. Jemt T, Pettersson PA. A 3-year follow-up study on single implant treatment. J Dent 1993: **21**: 203–208.
48. Jemt T. Modified single and short span restoration supported by osseointegrated fixtures in the partially edentulous jaw. J Prosthet Dent 1986: **55**: 243–246.
49. Jemt T. Regeneration of gingival papillae after single-implant treatment. Int J Periodontics Restorative Dent 1997: **17**: 326–333.
50. Jemt T. Restoring the gingival contour by means of provisional resin crowns after single-implant treatment. Int J Periodontics Restorative Dent 1999: **19**: 20–29.
51. Jovanovic SA, Nevins M. Bone formation utilizing titanium-reinforced barrier membranes. Int J Periodontics Restorative Dent 1995: **15**: 56–69.
52. Jovanovic SA, Spiekermann H, Richter EJ. Bone regeneration around titanium dental implants in dehisced defect sites: a clinical study. Int J Oral Maxillofac Implants 1992: **7**: 233–245.
53. Karlsson U, Gotfredsen K, Olsson C. Single-tooth replacement by osseointegrated Astra Tech dental implants: a 2-year report. Int J Prosthodont 1997: **10**: 318–324.
54. Kemppainen P, Eskola S, Ylipaavalniemi P. A comparative prospective clinical study of two single-tooth implants: a preliminary report of 102 implants. J Prosthet Dent 1997: **77**: 382–387.
55. Krump JR, Barnett BG. The immediate implant: a treatment alternative. Int J Oral Maxillofac Implants 1991: **6**: 19–23.
56. Laney WR, Jemt T, Harris D, Henry PJ, Krogh PHJ, Polozzi G, Zarb GA, Herrmann I. Osseointegrated implants for single-tooth replacement: progress report from a multicenter prespective study after 3 years. Int J Oral Maxillofac Implants 1994: **9**: 49–54.
57. Lang NP, Brägger U, Hämmerle CH, Sutter F. Immediate transmucosal implants using the principle of guided tissue regeneration. I. Rationale, clinical procedures and 30-month results. Clin Oral Implants Res 1994: **5**: 154–163.
58. Lazzara RJ. Immediate implant placement into extraction sites: surgical and restorative advantages. Int J Periodontics Restorative Dent 1989: **9**: 332–343.
59. Levine RA, Clem DS 3rd, Wilson TG Jr, Higginbottom F, Saunders SL. A multicenter retrospective analysis of the ITI implant system used for single-tooth replacements: preliminary results at 6 or more months of loading. Int J Oral Maxillofac Implants 1997: **12**: 237–242.
60. Levine RA, Clem DS 3rd, Wilson TG Jr, Higginbottom F, Solnit G. Multicenter retrospective analysis of the ITI implant system used for single-tooth replacements: results of loading for 2 or more years. Int J Oral Maxillofac Implants 1999: **14**: 516–520.
61. Lorenzoni M, Pertl C, Keil C, Wegscheider WA. Treatment of peri-implant defects with guided bone regeneration: a comparative clinical study with various membranes and bone grafts. Int J Oral Maxillofac Implants 1998: **13**: 639–646.
62. Malevez C, Hermans M, Daelemans P. Marginal bone levels at Brånemark system implants used for single tooth restoration. The influence of implant design and anatomical region. Clin Oral Implants Res 1996: **7**: 162–169.
63. Martin RJ, Goupil MT, Goldschmidt M. Single-implant segmental osteotomy: a case report. Int J Oral Maxillofac Implants 1998: **13**: 710–712.
64. Mattout P, Nowzari H, Mattout C. Clinical evaluation of guided bone regeneration at exposed parts of Brånemark dental implants with and without bone allograft. Clin Oral Implants Res 1995: **6**: 189–195.
65. Mayfield L, Nobreus N, Attstrom R, Linde A. Guided bone regeneration in dental implant treatment using a bioabsorbable membrane. Clin Oral Implants Res 1997: **8**: 10–17.
66. Mecall RA, Rosenfeld AL. Influence of residual ridge resorption patterns on fixture placement and tooth position. III. Presurgical assessment of ridge augmentation requirements. Int J Periodontics Restorative Dent 1996: **16**: 322–337.
67. Mellonig JT, Triplett RG. Guided tissue regeneration and endosseous dental implants. Int J Periodontics Restorative Dent 1993: **13**: 108–119.
68. Moberg LE, Kondell PA, Kullman L, Heimdahl A, Gynther GW. Evaluation of single-tooth restorations on ITI dental implants. A prospective study of 29 patients. Clin Oral Implants Res 1999: **10**: 45–53.
69. Neale D, Chee WW. Development of implant soft tissue emergence profile: a technique. J Prosthet Dent 1994: **71**: 364–368.
70. Nemcovsky CE, Artzi Z, Moses O. Rotated split palatal flap for soft tissue primary coverage over extraction sites with immediate implant placement. Description of the surgical procedure and clinical results. J Periodontol 1999: **70**: 926–934.
71. Nemcovsky CE, Moses O, Artzi Z. Interproximal papillae reconstruction in maxillary implants. J Periodontol 2000: **71**: 308–314.
72. Nir-Hadar O, Palmer M, Soskolne WA. Delayed immediate implants: alveolar bone changes during the healing period. Clin Oral Implants Res 1998: **9**: 26–33.
73. Norton MR. The Astra Tech Single-Tooth Implant System: a report on 27 consecutively placed and restored implants. Int J Periodontics Restorative Dent 1997: **17**: 574–583.
74. Nowzari H, Slots J. Microbiologic and clinical study of polytetrafluoroethylene membranes for guided bone regeneration around implants. Int J Oral Maxillofac Implants 1995: **10**: 67–73.
75. Oda T, Sawaki Y, Ueda M. Experimental alveolar ridge augmentation by distraction osteogenesis using a simple device that permits secondary implant placement. Int J Oral Maxillofac Implants 2000: **15**: 95–102.
76. Oda T, Sawaki Y, Ueda M. Alveolar ridge augmentation by distraction osteogenesis using titanium implants: an experimental study. Int J Oral Maxillofac Surg 1999: **28**: 151–156.
77. Ogiso M, Yamashita Y, Tabata T, Ramonito R, Borgese D. The delay method: a new surgical technique for enhancing the bone-binding capability of HAP implants to bone surrounding implant cavity preparations. J Biomed Mater Res 1994: **28**: 805–812.
78. Olsson M, Lindhe J, Marinello CP. On the relationship between crown form and clinical features of the gingiva in adolescents. J Clin Periodontol 1993: **20**: 570–577.
79. Oschsenbein C, Ross S. A reevaluation of osseous surgery. Dent Clin North Am 1969: **13**: 87–102.
80. Pallacci P, Ericsson I, Engstrand P, Rangert B, ed. Optimal implant positioning and soft tissue management for the Brånemark System. Chicago: Quintessence, 1995: 35–39.
81. Palmer RM, Smith BJ, Palmer PJ, Floyd PD. A prospective study of Astra single tooth implants. Clin Oral Implants Res 1997: **8**: 173–179.

82. Phillips K, Kois JC. Aesthetic peri-implant site development. The restorative connection. Dent Clin North Am 1998: **42**: 57–70.
83. Priest G. Single-tooth implants and their role in preserving remaining teeth: a 10-year survival study. Int J Oral Maxillofac Implants 1999: **14**: 181–188.
84. Quayle AA, Cawood J, Howell RA, Eldridge DJ, Smith GA. The immediate or delayed replacement of teeth by permucosal intra-osseous implants: the Tubingen implant system. 1. Implant design, rationale for use and pre-operative assessment. Br Dent J 1989: **166**: 365–370.
85. Rominger JW, Triplett RG. The use of guided tissue regeneration to improve implant osseointegration. J Oral Maxillofac Surg 1994: **52**: 106–113 (discussion 112–113).
86. Rosenquist B, Grenthe B. Immediate placement of implants into extraction sockets: implant survival. Int J Oral Maxillofac Implants 1996: **11**: 205–209.
87. Rosenquist B. A comparison of various methods of soft tissue management following the immediate placement of implants into extraction sockets. Int J Oral Maxillofac Implants 1997: **12**: 43–51.
88. Salama H, Salama M. The role of orthodontic extrusive remodeling in the enhancement of soft and hard tissue profiles prior to implant placement: a systematic approach to the management of extraction site defects. Int J Periodontics Restorative Dent 1993: **13**: 312–333.
89. Scheller H, Urgell JP, Kultje C, Klineberg I, Goldberg PV, Stevenson-Moore P, Alonso JM, Schaller M, Corria RM, Engquist B, Toreskog S, Kastenbaum F, Smith CR. A 5-year multicenter study on implant-supported single crown restorations. Int J Oral Maxillofac Implants 1998: **13**: 212–218.
90. Scholander S. A retrospective evaluation of 259 single-tooth replacements by the use of Brånemark implants. Int J Prosthodont 1999: **12**: 483–491.
91. Schwartz-Arad D, Chaushu G. Immediate implant placement: a procedure without incisions. J Periodontol 1998: **69**: 743–750.
92. Schwartz-Arad D, Chaushu G. Placement of implants into fresh extraction sites: 4 to 7 years retrospective evaluation of 95 immediate implants. J Periodontol 1997: **68**: 1110–1116.
93. Schultz AJ. Guided tissue regeneration (GTR) of nonsubmerged implants in immediate extraction sites. Pract Periodontics Aesthet Dent 1993: **5**: 59–66.
94. Scipioni A, Bruschi GB, Calesini G. The edentulous ridge expansion technique: a five-year study. Int J Periodontics Restorative Dent 1994: **14**: 451–459.
95. Scipioni A, Bruschi GB, Giargia M, Berglundh T, Lindhe J. Healing at implants with and without primary bone contact. An experimental study in dogs. Clin Oral Implants Res 1997: **8**: 39–47.
96. Seibert JS, Salama H. Alveolar ridge preservation and reconstruction. Periodontol 2000 1996: **11**: 69–84.
97. Simion M, Baldoni M, Rossi P, Zaffe D. A comparative study of the effectiveness of e-PTFE membranes with and without early exposure during the healing period. Int J Periodontics Restorative Dent 1994: **14**: 166–180.
98. Simion M, Baldoni M, Zaffe D. Jawbone enlargement using immediate implant placement associated with a split-crest technique and guided tissue regeneration. Int J Periodontics Restorative Dent 1992: **12**: 462–473.
99. Simion M, Misitano U, Gionso L, Salvato A. Treatment of dehiscences and fenestrations around dental implants using resorbable and nonresorbable membranes associated with bone autografts: a comparative clinical study. Int J Oral Maxillofac Implants 1997: **12**: 159–167.
100. Simion M, Scarano A, Gionso L, Piattelli A. Guided bone regeneration using resorbable and nonresorbable membranes: a comparative histologic study in humans. Int J Oral Maxillofac Implants 1996: **11**: 735–742.
101. Simion M, Trisi P, Piattelli A. Vertical ridge augmentation using a membrane technique associated with osseointegrated implants. Int J Periodontics Restorative Dent 1994: **14**: 496–511.
102. Summers RB. A new concept in maxillary implant surgery: the osteotome technique. Compendium Contin Educ Dent 1994: **15**: 152–162.
103. Summers RB. The osteotome technique. 2. The ridge expansion osteotomy (REO) procedure. Compendium Contin Educ Dent 1994: **15**: 422–436.
104. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal study covering 25 years. J Prosthet Dent 1972: **27**: 120–132.
105. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. J Periodontol 1992: **63**: 995–996.
106. Thilander B, Odman J, Jemt T. Single implants in the upper incisor region and their relationship to the adjacent teeth. An 8-year follow-up study. Clin Oral Implants Res 1999: **10**: 346–355.
107. Tjan AH, Miller GD, The JG. Some esthetic factors in a smile. J Prosthet Dent 1984: **51**: 24–28.
108. Tolman DE, Keller EE. Endosseous implant placement immediately following dental extraction and alveoloplasty: preliminary report with 6-year follow-up. Int J Oral Maxillofac Implants 1991: **6**: 24–28.
109. Wachtel HC, Langford A, Bernimoulin JP, Reichart P. Guided bone regeneration next to osseointegrated implants in humans. Int J Oral Maxillofac Implants 1991: **6**: 127–135.
110. Weeler RC. Complete crown form and the periodontium. J Prosthet Dent 1958: **11**: 722–734.
111. Weisgold A. Contours of the full crown restoration. Alpha Omegan 1977: **70**: 77–89.
112. Werbitt MJ, Goldberg PV. The immediate implant: bone preservation and bone regeneration. Int J Periodontics Restorative Dent 1992: **12**: 206–217.
113. Wohrle PS. Single-tooth replacement in the aesthetic zone with immediate provisionalization: fourteen consecutive case reports. Pract Periodontics Aesthet Dent 1998: **10**: 1107–1116.
114. Yukna RA. Clinical comparison of hydroxyapatite-coated titanium dental implants placed in fresh extraction sockets and healed sites. J Periodontol 1991: **62**: 468–472.