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The Root Membrane Technique: A Retrospective Clinical Study With Up to 10 Years of Follow-up

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Osseointegrated implants represent the most popular therapeutic solution for replacing compromised and nonrestorable teeth.^{1–3} A fixed implant-supported restoration must, however, be able to meet all the biological, functional, and aesthetic requirements, to be defined as truly successful.^{3–5} Until recently, the main focus of implant dentistry had been function and not aesthetics.^{5,6} Contemporaneously, however, implant rehabilitation is mainly focused toward aesthetic reconstruction of edentulism.^{5–8} A prerequisite for aesthetic success with a fixed implant-supported restoration is to maintain the bone anatomy, and the overlying soft-tissue architecture.^{7,8}

Extraction of 1 or more teeth causes alveolar bone resorption: this is a physiological phenomenon resulting from the fact that the periodontal ligament and its vascular support have been lost.^{9,10} The impairment of this vascular support has particularly marked consequences in the

Purpose: Immediate implant placement in conjunction with intentional root retention is a recently introduced technique, but the majority of existing documentation is limited to short-term reports with low level of evidence. Hence, the aim of this study was to document the long-term clinical and radiographic results of the root membrane technique.

Methods: This retrospective study reports on clinical results of the root membrane technique for periodontal ligament-mediated immediate implant placement with up to 10 years of follow-up from 3 private dental practices. Anterior implants placed with immediate loading from January 2006 to December 2016 were assessed. Kaplan-Meier estimators were computed for reporting of implant success and survival.

Results: A sample of 182 patients (82 men and 100 women, age range: 18–83 years) received 250 immediate implants (230 maxilla, 20 mandible) after the root membrane concept and followed-up for a mean of 49.94 months (± 32.5). Overall, 5 implant failures were recorded for a 10-year cumulative patient-level implant survival rate of 96.5%. Considering mechanical and biological complications, the 10-year cumulative implant success rate was 87.9%.

Conclusions: Within the limits of the retrospective design, the root membrane technique showed long-term success rates comparable to those of conventional immediate implants. (*Implant Dent* 2018;27:1–11)
Key Words: immediate implants, bone resorption, bone preservation, survival, success

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anterior maxilla, an area with high aesthetic impact, where the delicate and thin buccal bone receives most of its vascular contribution from the periodontal ligament.^{11,12} The consequence of this is resorption of the buccal bone wall, that is greater in the first months after the extraction of teeth,^{9,11,13} causing a contraction or recession of the overlying soft tissues and loss of the papilla, in the case of extraction of multiple elements.^{11,14} Such soft-tissue contraction does not in itself represent an impediment to the

placement of implants but may result in an aesthetic challenge for the clinician, particularly in the anterior areas of jaws.^{5,7,8,14}

Over the years, various surgical techniques have been developed to limit or counteract this physiological bone resorption following the extraction of 1 or more irreversibly compromised teeth in the anterior areas of the jaw.^{15–20} Among these, alone or in conjunction with implant placement, are several variants of socket preservation,^{16,17} gingival

grafts,¹⁸ and/or bone regeneration driven by biomaterials and membranes.^{19,20} Although all these methods can reduce the unpleasant aesthetic effects of the physiological bone resorption caused by the loss of teeth, none can completely halt this phenomenon because none target its causal effect, that is, the extraction of the tooth.^{9,11,13,14}

A possible alternative strategy for preserving the buccal bone, avoiding its resorption and the related contraction of the overlying soft tissues, is the maintenance *in situ* of the buccal portion of the root.²¹ The maintenance of the periodontal ligament and hence of the associated vessels may, in fact, prevent the physiological bone resorption of the buccal bone.²¹ It has long been known that root maintenance (also known as “root submergence technique”) can preserve the alveolar bone from resorption: such a technique has been successfully used in the edentulous areas of bridges.^{21–23} Recently, the same principles have been applied to implantology, by different groups of researchers, for the placement of immediate implants in areas with high aesthetic impact, such as the anterior maxilla.^{24–31} Hurzeler et al²¹ first coined the term “socket shield” technique. The technique consists of decoronating the compromised tooth and isolating the root that is dissected in the mesiodistal direction; the palatal (lingual) root portion is gently extracted while the buccal portion, in contact with the buccal bone, is left *in situ* after being reduced in thickness (to assume a concave shape similar to the profile of the bone crest) and in height (up to 1 mm above the bone ridge).^{24–26} The implant is positioned orally to the residual root portion and then the gap is managed or left to heal spontaneously.^{24–26} In fact, some suggest that the gap between the implant and the root membrane should be grafted,²² but published histological²¹ and clinical data²⁸ support that it is not necessary to fill the space between the residual root portion and the implant.

Although in recent years the attention of many clinicians has focused on this method, there are only a few clinical studies available with medium-term follow-up.^{26–28} To date, in fact, there are only 2 studies with a follow-up that reaches 5 years,^{26,28} and still

there are no clinical studies in the literature that document the outcomes of the root membrane technique in the long term³²; therefore, little is known about the possible long-term complications associated with this method, as emphasized by a recent literature review.³² In addition, there are clinical concerns that the placement of fixtures in contact or near dental roots can cause major complications (periimplant infection, bone loss) and that such complications can ultimately lead to the loss of the implant.^{33–35} Although in the reports concerning complications, the placement of implants near or in contact with dental roots or root portions was non-intentional,^{33–35} and therefore different from a planned and intentional insertion, it is certainly necessary to gather long-term clinical data to draw more precise conclusions about the reliability and safety of the root membrane technique. Thus, the aim of the present study was to document the long-term clinical and radiographic results of the root membrane technique with up to 10 years of follow-up.

MATERIALS AND METHODS

Patient Selection

Patients enrolled in the present retrospective study were identified through the customized records of 3

different private dental centers (2 centers in Greece and 1 in the United States).

Inclusion criteria were patients who had undergone single or multiple root membrane treatments, with immediate placement and restoration of single implants in the anterior maxilla and/or mandible (central and lateral incisors, cuspids, first premolars), in the period between January 2006 and December 2016. Only 1 of the 3 centers in Greece had documented cases treated between 2006 and 2007, whereas the remaining sites contributed cases from 2008 and onward. Additional inclusion criteria were a minimum follow-up of 12 months, and complete final recall/follow-up visit clinical and radiographic data. Exclusion criteria were patients with poor general health conditions (diabetic patients with poor glycemic control, severely immunocompromised patients, and patients undergoing chemotherapy or radiotherapy for head and neck malignancies), patients treated with amino-bisphosphonates, patients who did not have teeth in the opposing arch, patients with implants not loaded by a restoration for at least 6 months, and patients who failed to attend the final recall/follow-up visit.

A thorough review of the patients' records was conducted, to obtain all

Table 1. Patient Distribution by Gender, Age at Surgery (in Years), Smoking Habit, and History of Periodontal Disease

	No. of Patients (%)	<i>P</i> *
Gender		0.182
Male	82 (45.1)	
Female	100 (54.9)	
Age at surgery (y)		<0.0001
<20	2 (1.1)	
20–39	25 (13.7)	
40–59	92 (50.5)	
60–79	60 (33.0)	
≥80	3 (1.7)	
Smoking habit		<0.0001
No	139 (76.4)	
Light (<10 cigarettes/d)	15 (8.2)	
Strong (≥10 cigarettes/d)	28 (15.4)	
Periodontal lesions in other sites		<0.0001
No	163 (89.6)	
Yes	19 (10.4)	
Total	182 (100)	—

The distribution of patients was homogeneous by gender, but inhomogeneous by age at surgery (most of the patients aged >40 years), smoking habit (only a few patients were smokers), and history of periodontal disease (only a few patients had periodontal lesions in other sites of the mouth).

**P* = Chi-square test.

Table 2. Reasons for Tooth Failure and Replacement With an Immediate Implant Inserted With a Root Membrane

Reasons for Tooth Extraction	No. of Teeth (%)	<i>P</i> *
Tooth fracture	153 (61.2)	<0.0001
Destructive caries	91 (36.4)	
Internal/external root resorption	2 (0.8)	
Recurrent untreatable endodontic infection	4 (1.6)	
Total	250	—

The most frequent indications were tooth fracture and deep caries.
**P* = Chi-square test.

patient-related information (gender, age at surgery, presence or absence of smoking habit, presence of chronic periodontal lesions in other sites of the mouth). For presence of chronic periodontal lesions in other sites of the mouth, was meant the presence, in other sites of the oral cavity, of periodontal pockets (with probing pocket depth ≥ 6 –7 mm) or infrabony pockets, caused by previous chronic periodontal disease. The review of the patient's record included all tooth-related information (reasons for tooth failure, such as deep caries, tooth fractures, internal/external root resorption, and recurrent nontreatable endodontic lesions at the apex of the tooth) and implant-related information (implant site and position, implant type, length and diameter, date of installation, and date of provisional and definitive prosthesis delivery). In addition, the customized records of patients included all information about any implant failure and/or biological complication that occurred during the entire follow-up period because any complication that was manifested clinically was routinely referred back to the dentist for control; however, if it had not been registered in the customized records, the presence of any complications or failures could be intercepted during the last recall/follow-up visit in 2017. Data were gathered without identifiers and were analyzed for implant survival and success.

Surgical and Prosthetic Procedures

The surgical and prosthetic procedures followed here were as previously described.^{28,29} Briefly, after infiltration anesthesia, the crown of the compromised tooth was sectioned under abundant physiological irrigation, so that the residual root remained approximately 1 mm above the bone crest. The root

was then sectioned from mesial to distal, so as to obtain 2 identical halves (1 buccal and 1 palatal/lingual portion); the palatal/lingual portion was then carefully mobilized, using periosteal elevators or periostomes, and consequently extracted, taking care not to damage nor mobilize the buccal root portion. The buccal portion (ie, the root membrane) was therefore reduced to a thickness of 1.5 mm and made concave; the stability of the root membrane was again checked, then it was possible to proceed with the preparation of the implant site and the subsequent positioning of the implant.

The implant site was prepared through a series of drills of incremental

diameter, as suggested by the manufacturer, using the implant drill through the long axis of the root membrane. The implant was inserted palatally/lingually to the root membrane, into the socket. Two different types of implants were used in this study: cylindrical implants with self-tapping threads and a sand-blasted surface (EzPlus; MegaGen, Gyeongbuk, South Korea) or tapered implants with knife-edge threads and a nanostructured calcium-incorporated surface (Anyridge; MegaGen).^{30,36,37} The surgeon was free to choose between different implant diameters and lengths, both for the Ezplus (diameters 3.3, 4.0, 4.5, and 5.0 mm; lengths 8.5, 10, 11.5, 13, and 15 mm) and for the Anyridge system (diameters 3.5, 4.0, 4.5, and 5.0 mm; lengths 8.5, 10, 11.5, 13, and 15 mm). The choice of the length of the implant depended on the need to engage the same for at least 3 to 4 mm apically to the socket, as per protocol in the case of immediate placement, to guarantee adequate stability. If the stability was not sufficient and in the case of large sockets, the choice fell on a larger implant diameter, to

Table 3. Implant Distribution by Site, Position, Type, Length, and Diameter

	No. of Fixtures	<i>P</i> *
Site		<0.0001
Maxilla	230 (92%)	
Mandible	20 (8%)	
Position		0.0127
Central incisor	75 (30%)	
Lateral incisor	70 (28%)	
Cuspid	64 (25.6%)	
First premolar	41 (16.4%)	
Type		<0.0001
Cylindrical, self-tapping threads implants	38 (15.2%)	
Tapered, knife-edge threads implants	212 (84.8%)	
Length (mm)		<0.0001
Short (8.5 mm)	4 (1.6%)	
Regular (10 mm)	52 (20.8%)	
Regular (11.5 mm)	100 (40%)	
Regular (13 mm)	85 (34%)	
Long (15 mm)	9 (3.6%)	
Diameter (mm)		<0.0001
Small (3.3/3.5 mm)	88 (35.2%)	
Regular (4.0 mm)	83 (33.2%)	
Regular (4.5 mm)	49 (19.6%)	
Wide (5.0 mm)	30 (12%)	
Total	250	—

Most of the implants were placed in the maxilla, in the area of the central/lateral incisors, and were standard in length and diameter. The most frequently used fixtures were tapered, with knife-edge thread design.

**P* = Chi-square test.

promote stabilization. All implants were placed using an implant handpiece set at 25 rpm, and an abutment was placed after fixture insertion.

After implant placement, if a space remained between the fixture and the root membrane, this space was not filled with biomaterials of any kind, but it was allowed to heal spontaneously, without any grafting procedure.

All implants were then immediately restored with a cement-retained acrylic provisional restoration fabricated chairside or in a dental laboratory, as conventionally for immediate implant placement in the aesthetic zone. This temporary crown was appropriately relined, finished, and carefully polished; occlusion was carefully checked to avoid any static and/or functional contact with the opposing dentition.

Patients were then left with post-surgical instructions, including antibiotic prescription and analgesic medication, based on each patient's medical history. Patients were asked to rinse with chlorhexidine 0.12%, 3 to 4 times per day for a period of 1 week postintervention; they were instructed to defer from tooth brushing or any mechanical trauma in the area for 2 weeks. Two weeks after implant placement, patients were recalled for the first postoperative follow-up control. The period of provisionalization lasted for 2 to 3 months, after which the temporary crowns were replaced by the definitive metal-ceramic or zirconia-ceramic crowns. The patient was enrolled in a program of recalls and controls, with a minimum of 3 annual visits (1 every 4 months), in which he/she was subjected to a professional oral hygiene session and an accurate clinical examination, where necessary periapical radiographs were taken to control the hard tissue stability.

Outcome Variables

The outcome measures for the present study were implant survival and success.

Implant survival. A fixture was defined as "surviving" if it was clinically stable and regularly in function, at the final recall/follow-up visit; in all cases in

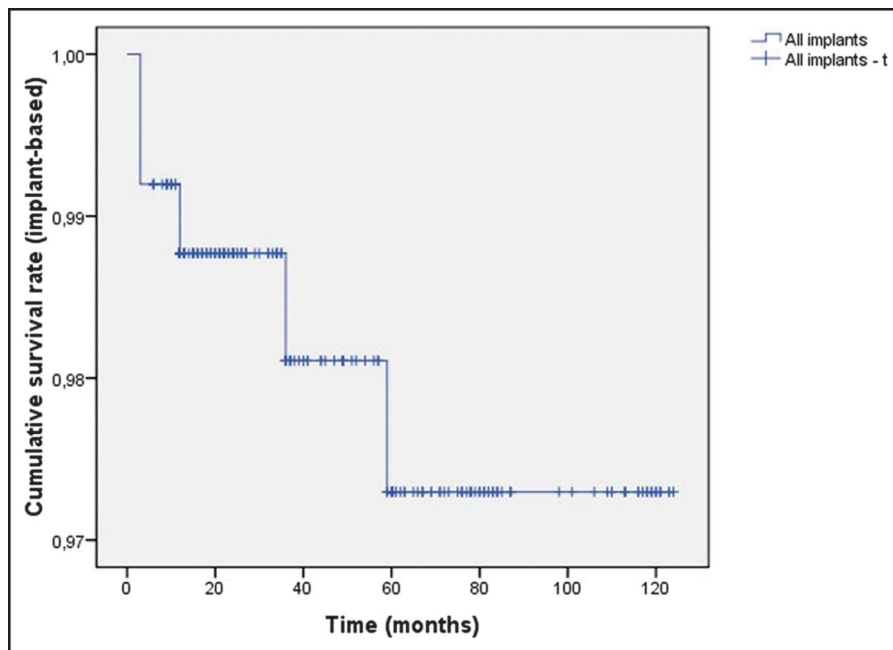


Fig. 1. Cumulative implant survival rate (implant-based). A 10-year cumulative implant survival rate of 97.3% was found at the implant level.

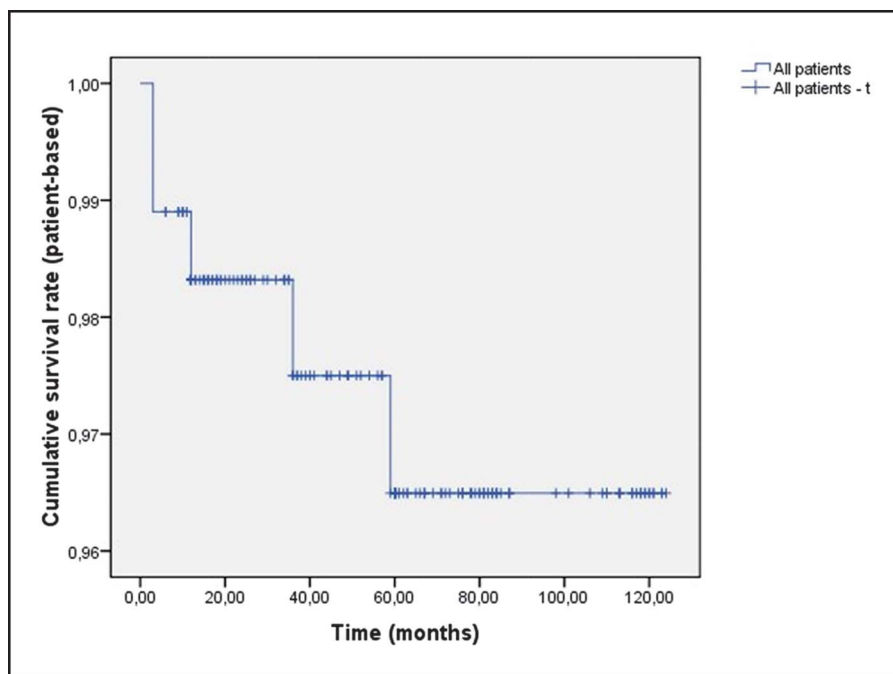


Fig. 2. Cumulative implant survival rate (patient-based). A 10-year cumulative implant survival rate of 96.5% was found at the patient level.

which an implant had to be removed, the fixture was defined as "failed."

The causes for implant removal were:

1. Infection of the implant and/or the root fragment immediately after

the surgery, with the subsequent failure of osseointegration;

2. Clinical implant mobility due to lack of osseointegration without any sign of infection;
3. Untreatable periimplantitis with pain, suppuration, and massive

- bone loss with subsequent implant loosening;
4. Implant body fracture.

Implant success. A fixture was considered successful in the absence of any biological complication, after the surgery and during the entire follow-up period. The biological complications were defined as complications affecting the implant, the root membrane, and the periimplant hard and soft tissues.^{21,22,27,30,31}

The biological complications were:

1. Pain and/or discomfort, edema, and/or swelling after surgery;
2. Root fragment exposure;
3. Root fragment mobilization;
4. Root fragment infection;
5. Root fragment resorption;
6. Periimplant mucositis, with inflammation of the periimplant soft tissues, bleeding on probing and/or suppuration associated with a pocket depth ≥ 4 mm, but no radiographic bone loss;
7. Periimplantitis, with inflammation of the periimplant hard and soft tissues, bleeding on probing and/or pus secretion associated with pocket depth ≥ 4 mm and radiographic evidence of bone loss (>2.5 mm).

Statistical Analysis

Data were collected and analyzed by a masked independent investigator who was not directly involved in the treatment of patients. No identifiers were maintained. The statistical analysis included a descriptive part, evaluating patient demographics (gender, age, smoking habit, and presence of chronic periodontal disease in other sites of the mouth), the reasons for tooth failure (deep caries, tooth fractures, internal/external root resorption, recurrent non-treatable endodontic lesions at the apex of the tooth), and the features of the inserted implants (site, position, length, diameter, and bone quality at the recipient site). All qualitative variables (such as patient and implant distribution, as well as the reasons for tooth failure) were expressed as absolute numbers (n) and relative frequency distributions (in

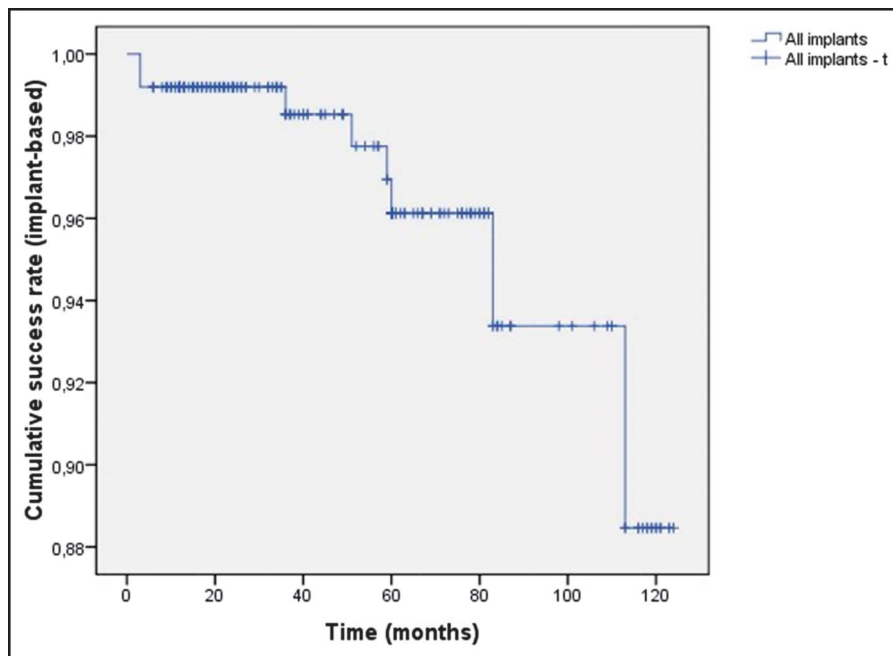


Fig. 3. Cumulative implant success rate (implant-based). A 10-year cumulative implant success of 88.5% was found at the implant level.

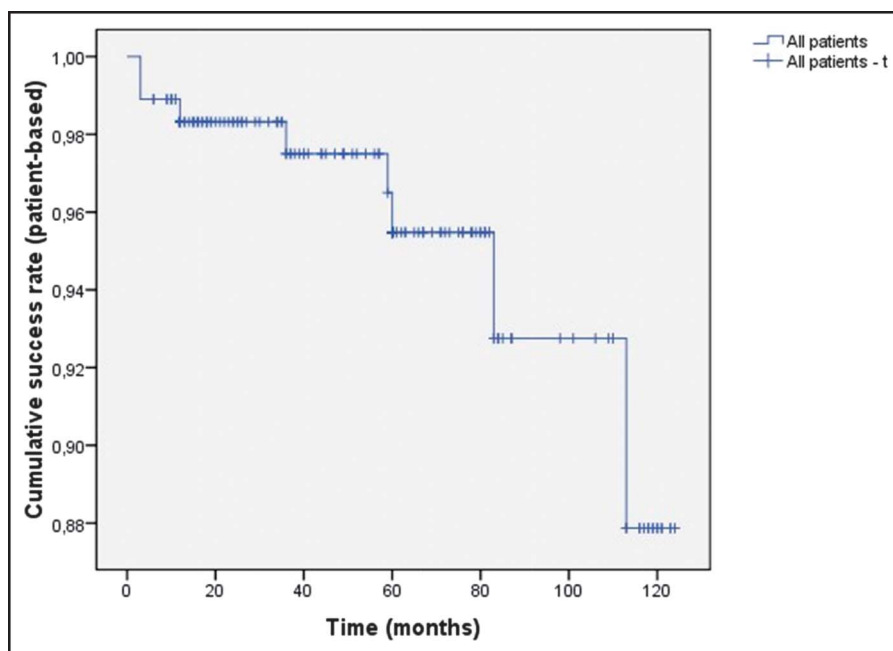


Fig. 4. Cumulative implant success rate (patient-based). A 10-year cumulative implant success of 87.9% was found at the patient level.

percentages). The Chi-square test was used to evaluate the uniformity in the distribution of patients, failed teeth, and implants, in the different groups, with the significance level set at 0.005. Mean values, SDs, medians, and 95% confidence intervals (CIs) were estimated for quantitative variables. The cumulative

survival and success rates were calculated at the patient level and at the implant level, using the Kaplan-Meier survival estimator.³⁸ In the case of multiple implant placement in a single patient, the presence of only 1 implant failure resulted in the insertion of the subject in the category of failures; the

same setting was valid for complications, as where only 1 biological complication occurred, the implant and the patient were automatically included in the failures category.

RESULTS

Overall, 182 patients were selected for inclusion in the present retrospective study (82 men and 100 women), between 18 and 83 years of age (mean age 53.5 years, SD 12.9, median 55, 95% CI: 51.6–55.4). The distribution of the patients is summarized in Table 1 and was uniform for gender ($P = 0.182$), but strongly inhomogeneous ($P < 0.0001$) for what concerns the age classes, the smoking habit, and the presence of chronic periodontal lesions in other sites of the mouth. In fact, the majority of the selected patients were in the 40- to 59-year-old group (92 patients, 50.5% of the total) and in the 60- to 79-year-old group (60 patients, 33% of the total), with only 27 patients younger than 40 years of age and 3 patients at age ≥ 80 years. Finally, 43 patients were smokers (representing 23.6% of the total): among these, 15 were considered light smokers because they smoked < 10 cigarettes/d, whereas 28 were classified like heavy smokers, because they smoked ≥ 10 cigarettes/d. Regarding the presence of periodontal lesions, only 19 of the patients (10.4%) had history of chronic periodontal disease, and therefore

presented, in other sites of the oral cavity, lesions such as periodontal and infrabony pockets.

The causes for tooth failure are summarized in Table 2. The most frequent indication for replacement of a failed tooth with an immediate implant and the root membrane technique was horizontal tooth fracture (153 cases, 61.2%), followed by deep caries (91 cases, 36.4%); the least frequent indications were recurrent non-treatable endodontic lesions at the tooth apex (4 cases, 1.6%) and internal/external root resorptions (2 cases, 0.8%). There was a strong lack of homogeneity in the distribution of the causes of dental failures ($P < 0.0001$).

In total, 250 immediate implants were placed to replace the failed, non-restorable teeth, following the root membrane concept. The distribution of the implants is summarized in Table 3. Two hundred thirty fixtures (92%) were inserted in the maxilla, and only 20 fixtures (8%) were placed in the mandible; therefore, the distribution of the implants by site was strongly inhomogeneous ($P < 0.0001$). The most frequent indication was the replacement of central incisors (75 implants, 30%), followed by lateral incisors (70 implants, 28%) and cuspids (64 implants, 25.6%). The least frequent indication was the replacement of first premolars (41 implants, 16.4%). No significant differences were reported in the distribution of the implants by position ($P =$

0.0127). Most of the implants were tapered with knife-edge threads and a nanostructured calcium-incorporated surface (212, 84.8%), and only 38 fixtures (15.2%) were cylindrical with self-tapping threads and a sandblasted surface; however, the latter were those that had the longest follow-up because they were the only ones available in the period between January 2006 and December 2012. With regard to the implant length, the most commonly used implants were regular 11.5- to 13.0-mm implants (100 and 85 implants, respectively, representing the 74% of all fixtures placed), followed by 10-mm implants (52 implants, 20.8%). Long (15-mm) and short (8.5-mm) implants were few (9 and 4 fixtures, respectively, representing 5.2% of all fixtures placed); thus, there was a strong lack of homogeneity in the distribution of implants by length ($P < 0.0001$). Finally, with regard to implant diameter, the most frequently used were narrow-diameter implants (3.3–3.5 mm diameter), which amounted to 88 (35.2%), followed by regular 4.0-mm diameter implants, which amounted to 83 (33.2%). Together, the diameters of 3.5 and 4.0 mm represented 171 implants, or 68.4% of the total. Only 49 implants (19.6%) were 4.5 mm in diameter, and there were 30 (12%) wide-diameter implants (5.0 mm). It was therefore evident that the distribution of the implants was inhomogeneous by diameter, with a marked

Table 4. Complications and Failures Occurred During the Entire Follow-up

Gender	Age	Smoking Habit	History of Periodontitis	Implant Position	Time (mo)	Type of Complication	Implant Removal
Male	42	Yes	Yes	#13	113	Root fragment infection and periimplant mucositis	No
Female	37	No	No	#11	83	Root fragment infection with fistula	No
Male	59	No	No	#24	59	Root fragment infection and periimplantitis	Yes
Female	53	No	No	#21	51	Root fragment infection with fistula	No
Male	64	No	No	#22	36	Periimplantitis	Yes
Male	71	No	No	#14	12	Root fragment infection and periimplantitis	Yes
Male	57	No	No	#34	3	Implant mobility in the absence of infection	Yes
Female	42	Yes	Yes	#12	3	Implant mobility in the absence of infection	Yes

A very limited number of failures and complications was evidenced during the entire study.

tendency in favor of smaller diameter fixtures ($P < 0.0001$).

The mean follow-up time was 49.94 months (± 32.5); however, 10 patients had a follow-up of 10 years, 15 patients had a follow-up of 9 years, and 10 other patients had a follow-up of 8 years, for a total of 35 patients with a long-term evaluation (8–10 years of follow-up). Overall, there were 5 implant failures, for a 10-year cumulative implant survival of 97.3% (implant-based) and 96.5% (patient-based), respectively (Figs. 1 and 2). In detail, 2 implants were removed 3 months after insertion because they were mobile, even without infection. This mobilization was attributed to the failure of osseointegration. The other 3 implants, on the other hand, were removed due to the presence of recurrent untreatable peri-implantitis with pain, suppuration, and massive bone loss. These implants were removed at 12, 36, and 59 months after placement, respectively. In 1 of these cases (at 36 months), the root membrane was left *in situ* because it was stable and apparently not affected by the infection, whereas in the other 2 cases (at 12 and 59 months), the root portion was removed, as it was identified as the triggering cause of the inflammatory process. In these last 2 cases, in fact, there was exposure of the root portion that was infected with suppuration and fistula formation: this inflammatory process involved the implant and determined the establishment of nontreatable and recurrent periimplantitis, with massive bone loss and mobilization of the fixture.

With regard to complications, the 10-year cumulative implant success was therefore 88.5% (implant-based) and 87.9% (patient-based), respectively (Figs. 3 and 4). The complications were the infection of the root portion, with suppuration and fistula formation, which occurred in 4 cases (at 83, 51, 59, and 12 months after implant insertion, respectively) and the infection of the root associated with periimplant mucositis in 1 case (at 113 months from the insertion of the fixture). The infection of the root membrane with fistula determined in 50% of cases the occurrence of periimplantitis that caused the loss of 2 implants (at 12 and 59 months after insertion). In the remaining 50% of cases, however, the implant was not affected by the infection

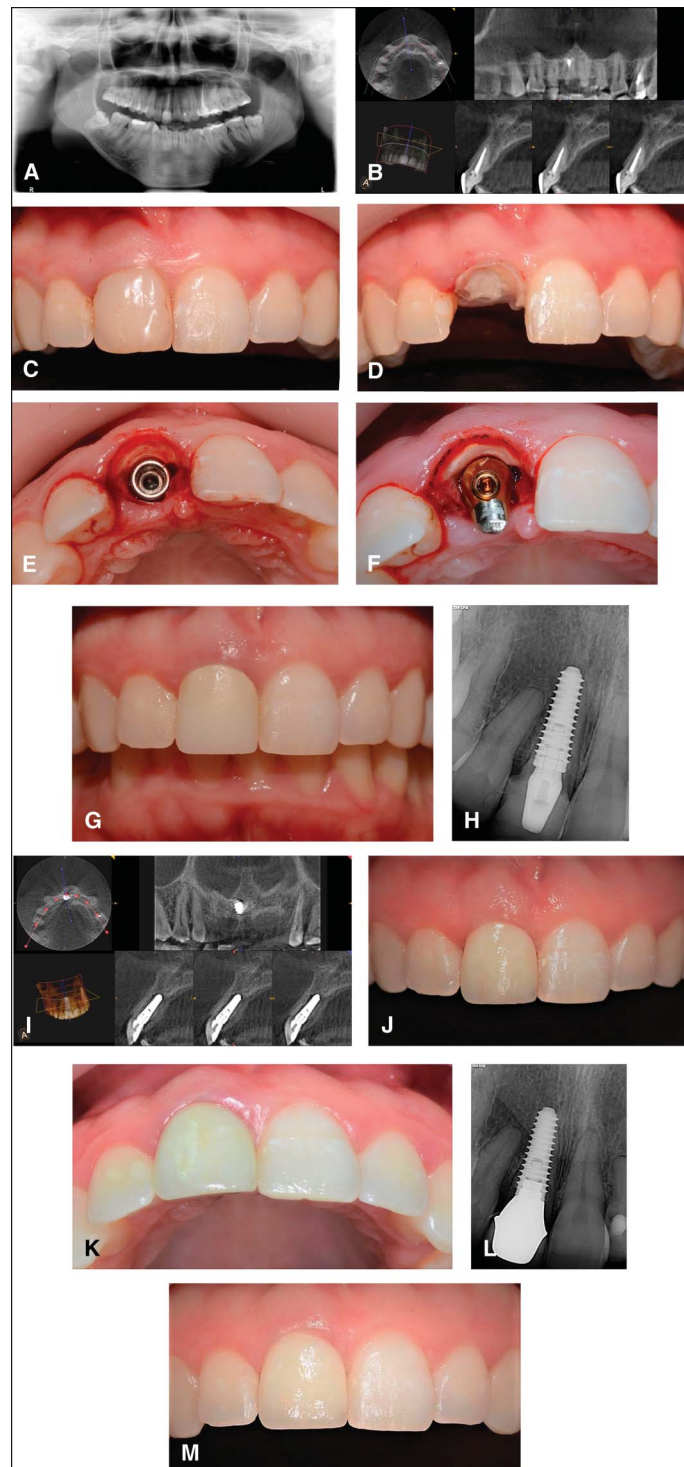


Fig. 5. Replacement of a fractured central incisor (#11) with an immediate implant and the root membrane technique: (A) initial panoramic radiograph; (B) computed tomography evaluation; (C) initial clinical view of the fractured tooth; (D) the tooth has a horizontal fracture; (E) immediate implant placement with the root membrane technique; (F) temporary abutment placed immediately after implant placement; (G) immediate provisional restoration; (H) peri-apical radiograph after immediate implant placement and delivery of the provisional restoration; (I) cone beam computed tomography at placement; (J) the final restoration after cementation; (K) occlusal-buccal view immediately after the delivery of the final restoration; (L) peri-apical radiograph taken 8 years after implant placement; (M) 8-year follow-up clinical view.

and the removal of the root fragment, together with antibiotic therapy, resolved the pathology. Periimplant mucositis caused by root membrane infection was also successfully treated with antibiotic therapy and professional hygiene sessions in a heavy smoker with history of periodontal disease, 113 months after insertion. In this case, the root was not mobilized and was therefore maintained *in situ*.

The details of implant failures and biological complications occurring during the study period are reported in Table 4.

A complete case is shown in Figure 5.

DISCUSSION

The root membrane technique has gained great popularity around the world in recent years, but still there are only few clinical researches that scientifically document its reliability,^{26–28,32} with no studies documenting the long-term outcomes of this technique.³² To date, in fact, most of the available articles reporting on this technique are case reports^{22,25,29,39,40} or case series.⁴¹ Only 1 randomized controlled trial³¹ and 1 prospective clinical study³⁰ are currently available in the literature, but both these studies are short-term, with a limited number of enrolled patients; finally, there are 3 studies on a larger sample of patients and with a follow-up of 4 to 5 years, but both these are retrospective in nature.^{26–28}

In a randomized controlled trial with 3 years of follow-up, Bramanti et al³¹ divided 40 patients into 2 groups: 20 patients received a single immediate postextraction implant in the aesthetic zone, with the socket shield technique (test group), and the other 20 patients received an immediate implant without the socket shield (control group). The outcome measures were implant survival, marginal bone levels, and aesthetic outcome by means of the pink aesthetic score (PES).³¹ Three years after placement, no implants were lost, for a survival rate of 100% in both groups. A marginal bone resorption of 0.60 mm (± 0.10) and 1.11 mm (± 0.13) was reported at 3 years, for the test and control groups, respectively; therefore,

a statistically significant difference was found between the 2 groups.³¹ Similarly, at 3 years, a statistically significant difference was found between the 2 groups with regard to the aesthetic evaluation, with a PES of 12.1 (± 0.8) and 10.3 (± 1.5) for the test and control groups, respectively.³¹ The authors concluded that fixtures inserted with the socket shield technique showed a survival similar to those of the control group, with better values of both marginal bone level and PES.³¹

In a prospective clinical study with 1 year of follow-up, Han et al³⁰ selected 30 patients and treated them with 40 immediate implants, according to a “modified” socket shield technique. The modification of the original technique described by Hurzeler in 2010²⁴ consisted of the reduction of the shield at the bone crest level (and not 1 mm above it, as originally described), with a thickness of 1.5 mm and a concave profile; in addition, no graft material was placed in the space between the shield and the implant in accordance with Mitsias et al^{28,29,41} but in contrast with Gluckman et al,^{22,27} who suggest this empty space should always be grafted with particulate material. After 1 year, all implants survived with an excellent mean implant stability quotient (ISQ) both at placement (ISQ = 72.9 \pm 5.9) and 1 year afterward (ISQ = 74.6 \pm 2.7).³⁰ In this study, no biological complications occurred, as the root fragments did not interfere with osseointegration; therefore, the authors concluded that a “modified” socket shield technique seems to be a successful procedure when combined with immediate implant placement, protecting the buccal bone from resorption and with beneficial effects on the aesthetics.³⁰

Both these 2 studies are important because they are prospective in design; however, they have 2 major limits, that is, the low number of enrolled patients and the limited follow-up time.^{30,31}

As previously reported, only 3 retrospective clinical studies report the clinical results in the use of the root membrane technique on a larger number of patients, and with a follow-up of 4 to 5 years.^{26–28}

In a retrospective clinical study published in 2014, Siormpas et al²⁸ reported the results obtained with the root

membrane technique in the anterior maxilla of 46 patients. In this study, immediate placement of 46 single implants (1 fixture per patient) with simultaneous intentional retention of the buccal bone aspect of the root was performed, and implant survival of up to 5 years of loading was reported, along with complications.²⁸ At the end of the follow-up period, all fixtures were functioning, for a 100% survival rate.²⁸ Excellent bone stability was reported, with mean crestal bone loss on the mesial and distal aspects of the fixtures of 0.18 mm (± 0.09) and 0.21 mm (± 0.09), respectively.²⁸ The soft tissues appeared stable, and only 1 biological complication was reported, namely, the apical root resorption of a single retained root fragment; this complication, however, did not jeopardize the osseointegration of the implant.²⁸

In a more recent retrospective study published by Baumer et al,²⁶ the authors investigated the reliability of the “socket shield” technique by evaluating the incidence of biological and implant-related complications, and reporting on the aesthetic outcomes, the conditions of the peri-implant soft tissues, and the volumetric changes of the facial contours. The authors followed 10 patients (who had been treated with immediate implant placed in the anterior maxilla with the socket shield technique) for a period of 5 years after the extraction of the tooth and placement of the implant.²⁶ In this study, impressions were taken before tooth extraction and 5 years postimplant placement, and the stone casts were scanned and digitally superimposed for a detailed qualitative/quantitative evaluation of the alterations of the periimplant tissue contours.²⁶ In addition, the ≥ 5 -year postloading clinical and radiographic data were collected.²⁶ Five years after placement, all implants were functioning,²⁶ and the periimplant bone was stable, with a mean bone loss of 0.33 mm (± 0.43) and 0.17 mm (± 0.36) at the mesial and distal aspects of the fixtures, respectively.²⁶ The soft tissues were stable too, with a mean tissue loss on the facial side in orofacial direction of 0.21 mm (± 0.18), and an average recession at fixtures and at neighboring teeth was 0.33 mm (± 0.23) and

0.38 mm (± 0.27), respectively.²⁶ Finally, the mean PES was 12.28.²⁶ The authors concluded that a low degree of contour changes from extraction and implant placement to the 5-year follow-up was evidenced, with recession at the implants that was comparable to those of the neighboring teeth.²⁶

Finally, in a retrospective clinical study with up to 4 years of follow-up, Gluckman et al²⁷ reported on the survival rate and complications of 128 immediate implants inserted in both jaws, according to the partial extraction therapy (PET) concept. At the end of the study, a survival rate of 96.1% (123/128 osseointegrated fixtures) was reported, with 20 complications registered and successfully managed among the surviving implants.²⁷ The authors concluded that the PET technique performed comparably to conventional delayed and immediate implant placement in implant survival and complications, at least in the mid-term.²⁷

Despite all the aforementioned studies on the root membrane/socket shield/PET technique, which reported excellent results of implant survival and low incidence of biological complications,^{26–28,30,31} the absence of a clinical study with long-term results in the literature has represented until now a limitation to the use of this technique; this is because little was known about the potential risks and complications related to it in the long term.³² Moreover, recently, some authors had placed the attention on the long-term risks related to implant placement in contiguity with or proximity to tooth roots, such as periimplant infection, bone loss, and implant failure.^{33–35}

The aim of our present retrospective study was therefore to shed light on the long-term survival rate (up to 10 years) of immediate implants inserted in the anterior areas of the jaw with the root membrane technique, and to evaluate the incidence of any biological complications occurring on the fixtures. In total, 182 patients (82 men and 100 women) were selected for inclusion in our study. Most of these patients were adults, between 40 and 70 years of age (152 patients, 83.5% of the total), and about a quarter of them (43, 23.6% of

the total) were smokers, but only a few (19, 10.4% of the total) had periodontal lesions in other sites. In these patients, 250 immediate implants (230 maxilla, 20 mandible) were placed via the root membrane technique. Most of the implants were inserted to replace a fractured tooth (153 fixtures, 61.2% of the total) or a severely carious tooth that could no longer be restored (91 fixtures, 36.4% of the total). The mean follow-up time was 49.94 months (± 32.5). Overall, there were only 5 implant failures, for a satisfactory 10-year cumulative implant survival rate of 97.3% (implant-based) and 96.5% (patient-based). With regard to complications, there were 8 adverse events, only 2 of which contributed to implant failure. The 10-year cumulative implant success rate was therefore 88.5% (implant-based) and 87.9% (patient-based), respectively.

The present study therefore has the merit of having clarified how the root membrane technique can be considered safe and reliable, even in the long term because the number of biological complications found was rather low, and in line with the evidence already emerging from the first short-term^{22,25,29,39–41} and mid-term studies.^{26–28}

Today, the evidence that emerges from our present long-term clinical study, together with the results reported by previous studies,^{26–28} seems to have definitively clarified the safety and reliability of this surgical technique; to this must be added the evidence that has emerged from histological studies on animals^{24,42,43} and humans,^{44,45} which seem to confirm how the maintenance of the buccal portion of the root can effectively preserve the buccal bone plate from resorption over time, thus contributing to the stability of the overlying soft tissues.

In a recent human histologic and histomorphometric study, in fact, we have retrieved a fixture and the surrounding tissues from the anterior maxilla of a 68-year-old patient, who had been treated 5 years earlier with an immediate implant via the root membrane technique.⁴⁴ Five years after implant placement, the buccal bone plate was preserved without any sign

of resorption, and a healthy periodontal ligament was in evidence.⁴⁴ The implant showed excellent osseointegration, with high bone-to-implant contact (BIC = 76.2%).⁴⁴ Between the fixture and the root membrane, the apical and medial thirds were filled with compact, mature bone, and the coronal third was colonized by noninfiltrated connective tissue.⁴⁴

It is important to emphasize that in our present long-term clinical study, we did not use any particulate grafting material in the space between the implant and the root membrane (when this space was present). Healing was left spontaneous, through the formation of a competent coagulum and without any interference. This differentiates our present technique from PET as described by Gluckman et al,^{22,27} who consider it essential to graft this empty space with regenerative material. In the light of this difference, therefore, the results of our present work cannot be generalized to the PET technique and the 2 methods must necessarily be distinguished because they represent different entities.

It is moreover important to underline that the present technique has very precise clinical indications and absolute contraindications.^{21,22} The present technique finds its primary indication in the anterior areas of the jaw (areas with high aesthetic relevance), in the presence of horizontally fractured teeth or nonrestorable teeth with deep caries, endowed with healthy periodontal ligament or ankylosed, but stable.^{21,22} Tooth mobility (caused by chronic periodontitis, trauma, or other) represents an absolute contraindication to root membrane technique. With the root membrane technique, a correct preoperative evaluation of anatomy is certainly useful and necessary. Accordingly, a cone beam computed tomography evaluation of the preparation site and tooth can be extremely helpful for the clinician because it allows the visualization of any possible apical infection, resorption, fenestration and dehiscence, and in addition it offers the clinician information about root length and width. Finally, the technique is surgically complex and should be used only by expert operators, with appropriate

instrumentation. Surgical errors may, in fact, jeopardize the final results and pose a risk of implant failure. In all cases, atraumatic extraction is a key to the success of the surgical technique. If, during extraction and preparation, the membrane should become mobile, this must be extracted without delay. During preparation of the buccal portion of the root, sharp edges and overextension above the bone crest may result in exposure of the membrane through the soft tissue; any exposure in the absence of infection may be managed by soft-tissue closure, but in all cases where infection of the root section is coupled with mobility, removal of the membrane is mandatory.

Our present study has limits. In fact, despite the fact that it is a long-term study, it is retrospective; it is well known that the best study design from which to draw reliable conclusions is the prospective one, even better if in the presence of a control, as in the case of randomized clinical trials. Moreover, although our study examined a fair number of patients, the outcomes analyzed here were only implant survival and complications. This was certainly necessary to gather long-term data on the safety and reliability of the technique; however, because the aim of the present method was to reduce bone resorption of the buccal bone plate over time, and the related soft-tissue contraction, it would have been desirable to carry out an aesthetic evaluation and to examine the soft-tissue stability over time. In our present study, we only evaluated clinical outcomes, but we did not perform an aesthetic evaluation. Today, the best way to examine the soft-tissue stability over time is a 3-dimensional volumetric analysis, by means of different intraoral scans taken at different times, and then superimposed with reverse engineering software, to examine the soft-tissue variations in detail.⁴⁶ Only in this way will we be able to draw more specific and definitive conclusions about the efficacy of the root membrane technique, in preventing buccal bone resorption along with soft-tissue contraction, and thus determine a satisfactory and stable aesthetic result over time.

CONCLUSIONS

In the present retrospective clinical study, the intentional retention of the buccal aspect of the root with its periodontal apparatus during immediate implant placement leads to predictable clinical outcomes and satisfactory high survival and success rates in the long term. In fact, 250 immediate implants were placed in 182 patients, following the root membrane concept: the mean follow-up time was 49.94 months (± 32.5), and only 5 implants failed and had to be removed, or a 10-year cumulative implant survival rate of 97.3% (implant-based) and 96.5% (patient-based), respectively. With regard to complications, there were 8 adverse events. The 10-year cumulative implant success rate was therefore 88.5% (implant-based) and 87.9% (patient-based), respectively. Despite the good results obtained in this work, with high survival and success rates for implants placed in the maxillary anterior region with the root membrane technique, further studies with a thorough aesthetic examination are still needed to draw more specific conclusions about the efficacy of the present technique, in preserving buccal bone and soft-tissue aesthetics over time.

DISCLOSURE

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ROLES/CONTRIBUTIONS BY AUTHORS

K. D. Siormpas: Concept/design, data collection, data analysis/interpretation, critical revision of article, and approval of article. M. E. Mitsias: Concept/design, data collection, data analysis/interpretation, critical revision of article, and approval of article. G. A. Kotsakis: Concept/design, data analysis/interpretation, drafting article, critical revision of article, and approval of article. I. Tawil: Concept/design, data collection, data analysis/interpretation, drafting article, critical revision of article, and approval of article. M. A. Pikos: Data analysis/interpretation, drafting

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