Immediate Implant Placement in the Esthetic Zone Utilizing the "Root-Membrane" Technique: Clinical Results up to 5 Years Postloading

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Purpose: *To clinically evaluate immediate implant placement with simultaneous intentional retention of the buccal aspect of the root and to report longitudinal data on survival of implants placed with the use of this novel technique.* ***Materials and Methods:*** *A retrospective case series of implants placed with the root-membrane technique in the maxillary anterior region of adult patients was conducted. Clinical and radiographic analysis was performed to assess implant success and to evaluate the survival of the retained root fragment based on predetermined criteria. A Kaplan-Meier method analysis was used to estimate the 5-year success rate of implants placed with this technique.* ***Results:*** *Data from 46 patients (median follow-up time, 40 months; range, 24 to 60 months) were evaluated. Each patient contributed one implant site in this study. All implants successfully maintained osseointegration at the end of the follow-up period for a 100% cumulative survival rate, based on clinical and radiographic criteria. Radiographic examination revealed good crestal bone stability with mean crestal bone loss on the mesial and distal aspects of the implants estimated to be 0.18 ± 0.09 mm and 0.21 ± 0.09 mm, respectively. The only complication noted in this patient cohort was apical root resorption of a single retained root fragment that did not interfere with the osseointegration of the implant.* ***Conclusion:*** *The intentional retention of the buccal aspect of the root with its periodontal apparatus during immediate implant placement can lead to predictable and sustainable osseointegration of implants placed in the maxillary anterior region of healthy adults.* Int J Oral Maxillofac Implants 2014;29:1397–1405. doi: 10.11607/jomi.3707

Key words: *alveolar bone preservation, dental implant, dentin fragment, esthetics, immediate implant placement, root retention*

The replacement of a maxillary anterior tooth with an implant is a complex surgical procedure, mainly because of the cascade of events that follow every tooth extraction.[1,2] Alveolar ridge resorption is a physiologic process that cannot be entirely prevented based on current evidence.[3–8] Ridge resorption can be categorized as a multifactorial phenomenon that is partially attributed to the loss of blood supply that is derived from the periodontal ligament (PDL) prior to tooth extraction.[9]

The buccal plate of the teeth in the maxillary anterior dentition is most often very thin, leading to significant dimensional alterations during the immediate postextraction period.[10,11] The aforementioned alterations are three-dimensional and lead to apical migration of the soft tissue at the crest of the ridge as well as concavities on the flat facial surface of the ridge.[12] When an implant is placed in such a compromised site, it is very challenging for the clinician to achieve an esthetic emergence profile for the implant-supported restoration. Recreating a mucosal zenith at the same level as that of the gingival zenith points of the proximal teeth is equally challenging, even if significant tissue grafting is performed.[13]

In retrospective, early attempts for an evidence-based approach to the documentation of the magnitude and significance of this phenomenon can be dated back to the early 1960s.[14–16] The intentional retention of roots was the first approach that was introduced

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for the preservation of alveolar ridge dimensions.[17–19] This technique attracted significant attention prior to the outburst in the use of implants as the treatment of choice for the restoration of single edentulous sites. In contemporary implant-dominated clinical practice, root submergence is still recognized as a beneficial approach for pontic-site development.[20]

In the early 1990s, Buser and coworkers attempted to introduce a new concept: implants surrounded by a functional PDL.[21,22] Even though these animal studies failed to result in a "hybrid" implant that would be in indirect contact with the host's bone via perpendicular PDL fibers, a very important observation was made; the portion of the implant that was in contact with a retained portion of the root was covered by a layer of cementum populated by collagen fibers. This finding was later exploited by another group of researchers, who performed implant placement in contact with ankylosed root fragments of teeth in five consecutive clinical cases with notable success.[23] During the same period, a clinical study was published in which the technique of drilling with surgical burs through the roots of teeth for the preparation of the implant bed was introduced as a novel approach for atraumatic tooth extraction.[24] The outcome of the combination of these techniques was investigated in an animal study.[25] Results of this study showed that immediate implant placement with intentional preservation of the buccal portion of the root of a tooth may be an atraumatic approach that leads to preservation of the blood supply of the buccal plate and consequent preservation of the dimensions of the alveolar ridge.[25]

The implant rehabilitation of a tooth with a hopeless prognosis in the esthetic zone without esthetic compromise remains elusive to date. A variety of graft materials and techniques have been introduced to counter ridge resorption. All fail to fully compensate for the physiologic consequences of the compromised blood supply postextraction that leads to resorption of the bundle bone.[2,26] The rationale behind the intentional retention of the buccal aspect of the root with its periodontal apparatus is that a portion of the blood supply that derives from the PDL is maintained. Also, the flapless approach that is utilized, because burs are used to remove the root structures, allows for maintenance of the blood supply from the supraperiosteal artery that runs through the periosteum attached to the buccal plate of the ridge. This technique therefore facilitates the preservation of the esthetics of the ridge based on biologic principles rather than on use of any biomaterial. No study to date has reported longitudinal data from cases of nonankylosed teeth treated with this novel approach.

The aim of this retrospective case series was to evaluate the feasibility of this approach in a clinical practice setting and to report longitudinal data on survival of implants placed with the use of this innovative technique.

MATERIALS AND METHODS

Inclusion Criteria

The following are the inclusion criteria for the study: adult patients with a noncontributory medical history who presented with a single hopeless tooth in the maxillary anterior dentition and requested a treatment alternative that would be the least invasive and would require no bone grafting or adjunctive use of biomaterials to aid in bone regeneration.

Following a thorough oral evaluation, patients were informed about the diagnosis and treatment alternatives. It was explained to all potential participants how this treatment approach differed from routine implant treatment, and willing participants signed the consent form in which all treatment risks were explicitly reported before enrolling in the study. The study was conducted in accordance with the Helsinki Declaration of 1975 for medical studies, as revised in 2000.

Exclusion criteria were a medical history that contraindicated oral surgical treatment or that dictated chronic therapy with nonsteroidal anti-inflammatory drugs (NSAIDs), biphosphonates and/or corticosteroids, pregnancy, and acute inflammation. Sites with moderate or severe periodontal disease and/or sites exhibiting facial clinical attachment loss greater than 3 mm were also excluded.

Surgical Procedure

Following administration of local anesthesia, the crown of the involved tooth was removed with a conventional chamfer diamond bur under copious irrigation until the remaining tooth structure was leveled at no greater than 1 mm above the osseous crest. The reason for not reducing it to the level of, or even below, the osseous crest was to maintain the dentogingival fibers intact for enhancing soft tissue esthetics. The implant placement procedure was initiated following the drilling sequence suggested by the implant manufacturer, utilizing the implant drill through the long axis of the remaining root. The drilling was initiated to engage the palatal aspect of the root so that the buccal aspect would remain intact following preparation of the implant bed.

The goal after enlargement of the dentinotomy/osteotomy was to have an implant housing consisting of mesial, distal, and palatal bony walls, while the buccal wall of the housing would be occupied by the remaining buccal portion of the root comprised of a thin layer of dentin, followed by cementum, PDL, and bundle bone in an orofacial direction. Following implant bed preparation, a carbide bur (5909-040, Brasseler) was utilized to separate the buccal root portion from the remaining root structure by means of two axial indentations at the mesiobuccal and distobuccal line angles. The remaining root fragments from the lingual and proximal aspects were easily retrieved using root tip forceps or a periotome. A tapered implant (EZ Plus Internal, MegaGen Implant) was placed in proximity to the dentin of the retained root fragment. The choice of implant size was such that it would allow for the retention of a root section with at least 1 mm of thickness to ensure resistance to fracture. The implants were placed using an implant handpiece set at 20 rpm, and a final abutment was placed following seating of the implant. All implants were immediately loaded with a cement-retained acrylic interim restoration fabricated chairside as per routine protocol for immediate implant placement in the esthetic zone. Following fabrication of the interim restoration, a meticulous occlusal check was performed to ensure nonfunctional loading. Postsurgical instructions included antibiotics and analgesic medication based on each patient's medical history as well as a chlorhexidine 0.12% oral rinse. Patients were also instructed to defer from tooth brushing or any mechanical trauma in the area for 2 weeks. At 2 weeks the patient was asked to return for a postoperative evaluation.

Clinical and Radiographic Evaluation

All implants were evaluated for successful osseointegration 3 months postoperatively, and routine clinical protocol was employed for the fabrication of the definitive restoration.[27] Implant survival was evaluated clinically and radiographically at the delivery of the final restoration (baseline), at 6 months postloading, and at annual follow-up visits. Implant survival was evaluated using criteria defined by Buser et al[28] (1990) and Karoussis et al[29] (2004):

- Clinical: assessment of implant mobility, signs of peri-implantitis, and evaluation of patient-reported symptoms (pain, altered sensation)
- Radiographic: examination for continuous radiolucency around the implant and bone loss in excess of 0.2 mm annually after the first year

Survival of the root fragment was determined radiographically on digital periapical radiographs taken with the long-cone paralleling technique using Eggen holders. The radiographic evaluation of the retained root portion was performed on a biannual basis (at 2 years postloading and every 2 years thereafter) unless indicated earlier as determined on an individual basis, according to the criteria of Davarpanah and Szmukler-Moncler[23] (2009):

- Evaluation for abnormal reactions at the bone-implant interface
- Evaluation of possible resorption of the remaining root fragments
- For data-analysis purposes, implant success was defined as the combined survival of the implant and the "root-membrane," fulfilling all of the aforementioned criteria for both.

The radiographic crestal bone levels were evaluated on the periapical radiographs as previously described by Kotsakis and co-workers.[30] Briefly, the implant length in each radiograph was used as a reference length to calibrate for potential foreshortening or elongation of the radiographic image due to the angulation of the radiographic sensor. The proximal crestal bone levels were estimated by measuring the distance from the implant platform to the proximal bone level, mesially and distally. The difference between baseline and the 2-year postloading radiographic images was recorded to estimate proximal crestal bone remodeling. When available, cone beam computed tomography (CBCT) sections were also evaluated to determine the fate of the retained root fragment. In addition, clinical evaluation was performed to evaluate for any soft tissue dehiscence over the root fragment or other clinical findings associated with chronic inflammation (eg, fistula).

Statistical Analysis

Demographic, radiographic, and clinical data are presented descriptively. The Kaplan-Meier method was utilized to estimate the 5-year success rate of implants placed with this technique. Inserted implants were considered as the analysis unit. An implant was considered successful for statistical purposes if at the time of the review it fulfilled the dual criteria mentioned earlier. To estimate the 5-year Kaplan-Meier curve, patients who were followed up for less than 5 years were right-censored at appropriate time intervals based on the respective follow-up period. Statistical analyses of the data were carried out using R statistical software.[31]

RESULTS

Results from 46 patients (20 men and 26 women) and corresponding implants placed are reported in this study. The median patient age was 53 years (range, 28 to 70 years) with all patients contributing a single implant site in the study. The site distribution of placed implants is presented in Table 1.

Forty-five of the 46 included teeth were periodontally sound teeth that were diagnosed as nonrestorable due to extensive caries or supracrestal horizontal

Table 1 Distribution of Included Sites

	Site Distribution					
Tooth site*	6	7	8	9	10	11
Tooth site†	13	12	11	21	22	23
No. of sites	7	10	12	6	6	5

*Universal numbering system †FDI numbering system

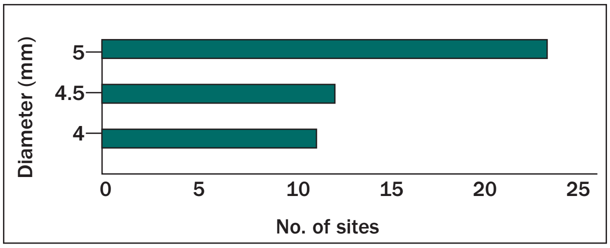

Fig 1 Selection of implant diameter in sites treated with the root-membrane technique.

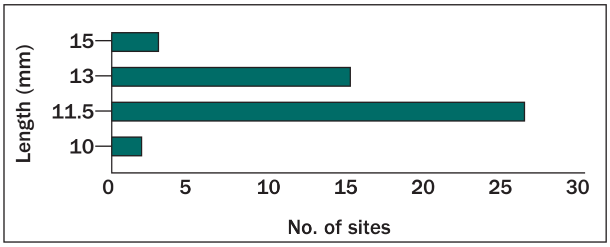

Fig 2 Selection of implant length in sites treated with the root-membrane technique.

fractures; 11 of those teeth were vital, and 34 had previously undergone root canal treatment. The remaining 1 tooth had a hopeless prognosis due to invasive cervical root resorption. Additional findings included ankylosis in 3 teeth, all of which were noted on teeth with previous root canal treatment. None of the included teeth had signs of acute infection.

The dimensions of implants placed ranged from 4.0 to 5.0 mm in diameter and from 10 to 15 mm in length (Figs 1 and 2). No graft materials, biologic factors, or membranes were used in any of the cases. All cases were provisionally rehabilitated with acrylic resin directly fabricated immediate restorations. The definitive restorations were porcelain-fused-to-metal cement-retained restorations that were delivered 4 to 6 months after implant placement.

Outcome Evaluation

Postoperative healing was uneventful in all cases. The median follow-up time was 40 months, with a minimum follow-up period of 24 months postloading (range, 24 to 60 months).

Clinical evaluation at 6 months and at the annual recall appointments revealed no complications associated with implant placement. Intraoral evaluation revealed good dimensional stability of the implant sites with the clinical characteristics of the peri-implant mucosa being indiscernible from those of the gingiva surrounding the proximal teeth. None of the patients reported subjective adverse events such as pain or altered sensation in the treated areas throughout the follow-up period (Figs 3a to 3f).

Radiographic evaluation was performed on data from periapical radiographs that were obtained at each patient's latest follow-up visit (Table 2). All patients demonstrated good bone stability around the implant platform. The mean crestal bone loss on the mesial and distal aspect of the implants was estimated to be 0.18 ± 0.09 and 0.21 ± 0.09 mm, respectively (Fig 4).

In 4 of 46 patients, a set of preoperative and postoperative CBCT images were available. Evaluation of CBCT cross sections revealed remarkable stability of the buccal plate in three of the four patients with radiographic signs of implant integration in the available bony walls. In regard to the radiographic appearance of the retained root fragment, observation of the cross sections revealed that the implant-root interface seemed to be delineated by a radiolucent line that was interrupted by areas of direct contact between the radiopaque root fragment and the titanium surface at either the coronal portion of the root fragment or the apical, depending on the angulation of the implant in reference to the retained root fragment (Fig 5). This finding may also be attributed to beam hardening. Titanium implants, like most metallic structures, may cause artifacts in CBCT images; therefore, this dark radiolucent line may simply represent a streak artifact.

The only complication in this study was noted in a nonsmoking male patient aged 31 years. In this patient, a 5.0-mm-diameter implant had been placed in the maxillary central incisor position. A periapical granulomatous defect was identified at the apex of the involved tooth and was meticulously curetted simultaneously with implant placement. Healing at the 6-month and 12-month evaluations was uneventful. Radiographic evaluation at 36 months postloading revealed apical root resorption of the retained root fragment that was estimated to be approximately 1.5 mm. Clinically, there were no signs of inflammation, and the implant exhibited no signs of mobility, pain upon percussion, or palpation. The patient did not have any symptoms that would indicate implant failure. Therefore, the patient was informed of the finding, and it was decided to monitor the site frequently and to maintain the current prosthesis. This patient has been followed up for 51 months with no recorded signs of implant failure or significant increase in root resorption. During radiographic examination at 48 months postloading, the area where root resorption had occurred seemed

Fig 3a Preoperative clinical view of a maxillary left central incisor that was planned for extraction because of significant resorption.

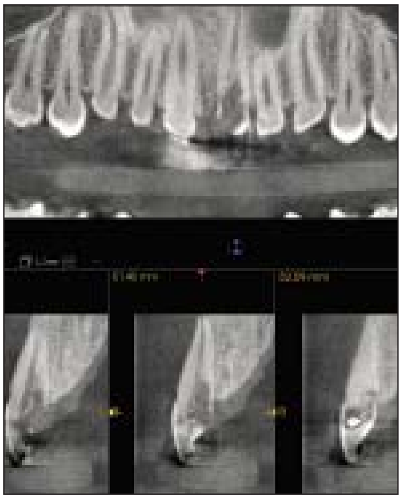

Fig 3b CBCT cross sections revealed significant loss of tooth structure consistent with invasive cervical root resorption. Note the limited thickness of the buccal plate. Extraction of the tooth would lead to a socket with unfavorable regenerative potential that presents a contraindication for conventional immediate implant placement.

Fig 3c Intraoperative view of flapless immediate implant placement near the retained buccal portion of the root. Note the supracrestal buccal root fragment in contact with the free gingival margin that has been retained to support the facial soft tissue via retention of dentogingival fibers. Following implant placement, the root fragment was reduced to approximately 0.5 to 1 mm supracrestally.

Fig 3d Clinical view of the immediate implant with the abutment in place to allow for immediate temporization. Note the retained tooth fragment on the facial.

Fig 3e Immediate acrylic resin provisional restoration directly fabricated and cemented in place. Note that the gingival zenith is apically positioned in relation to the gingival zenith of the neighboring teeth. Also note the concave cervical profile of the restoration, which is shaped to allow coronal creeping of the tissue.

Fig 3f Clinical view of the final restoration at the 2-year follow-up appointment. Creeping attachment of the facial gingiva has occurred, which allows for reconstitution of gingival esthetics. The importance of appropriate contouring of the interim restoration to allow for coronal migration of the tissue cannot be overstated. Prosthetically guided healing is required to exploit the potential of the root-membrane technique for gingival esthetics.

to be filled with radiopaque tissue with similar trabecularization to the neighboring bone, consistent with bone fill in the area. A CBCT scan obtained at 6 years postplacement verified resorption of the root apex and fill of the defect by radiopaque tissue with signs of trabecularization that verified a pending clinical diagnosis of replacement resorption (Fig 6).

Based on clinical criteria, all 46 implants survived during a minimum follow-up period of 24 months and up to 60 months. For the estimation of the 5-year success rate, the case that exhibited apical root resorption was considered a failure (Fig 7).

Table 2 Demographic Characteristics and Follow-up Time for Patients Included in the Study

Patients (n)	Median age (y) (range)	Follow-up (mo)
7 (5 men, 2 women)	54 (37–65)	24–30
18 (8 men, 10 women)	45 (28–65)	31–40
17 (5 men, 12 women)	54 (32–70)	41–50
4 (2 men, 2 women)	36 (29–64)	51–60
46 (20 men, 26 women)	53 (28–70)	24–60

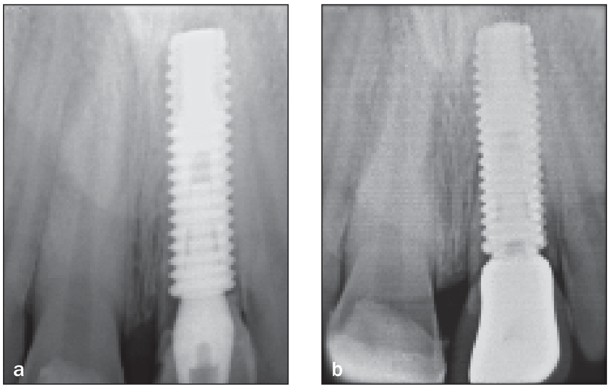

Fig 4 Periapical digital radiographs of the same clinical case taken immediately postloading, *(a)* baseline and *(b)* at the 4-year follow-up appointment, showing good stability of the crestal bone level. Note a shift in angle between the two radiographs, ie, the absence of distal interproximal space in *(b)*. The implant length was utilized for digital calibration of the radiographic image to compensate for elongation of the periapical radiograph.

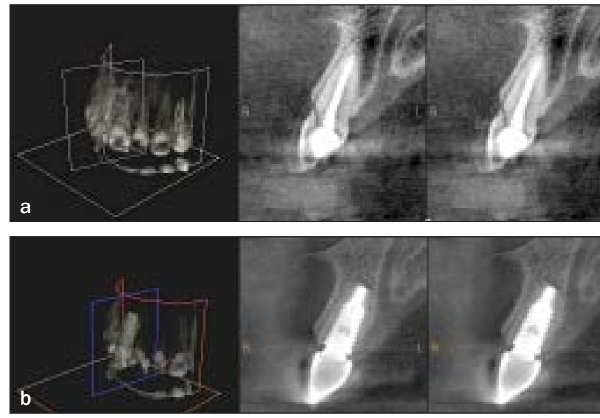

Fig 5 *(a)* Baseline and *(b)* 4-year follow-up CBCT cross sections showing satisfactory maintenance of the buccal plate on the facial aspect of the retained root fragment.

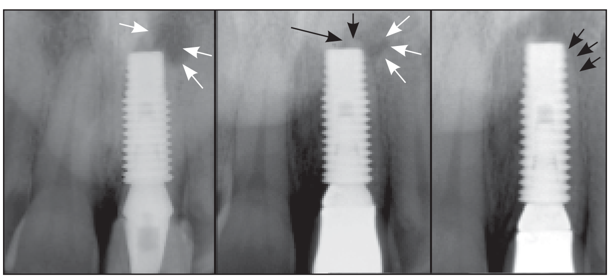

Fig 6a (*left*) Baseline periapical radiograph showing a periapical defect (*white arrows*). (*center*) The 24-month radiographic image revealed restriction of the size of the defect; the apex of the retained root portion is delineated (*black arrows*). (*right*) At 36 months, there were no signs of radiolucency, consistent with defect fill. Resorption of the apex of the root was noted.

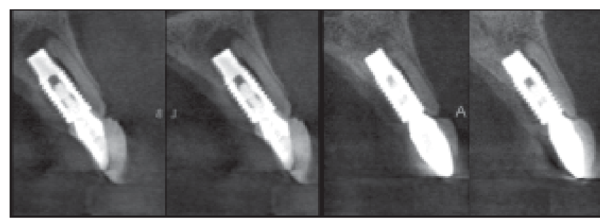

Fig 6b *(left)* Baseline CBCT cross sections showing the periapical bone defect that was meticulously degranulated prior to implant placement. *(right)* Cross sections at the 48-month follow-up revealed complete defect fill and approximately 1.5 mm of root resorption. The area of resorption is filled with new tissue with radiographic patterns indicating new bone growth.

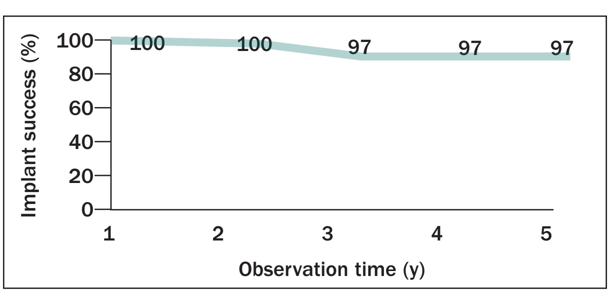

Fig 7 5-year Kaplan-Meier analysis curve.

DISCUSSION

The root-membrane technique presented in this study is an alternative treatment modality for immediate implant placement in the esthetic zone. Results showed that for specific indications and with the use of stringent exclusion criteria, this technique yields a very high implant success rate that is directly comparable to longitudinal data on immediate implant placement following complete root extraction.[32] In the present study sample, one root fragment exhibited signs of resorption, yet the implant remained functional for a 100% cumulative survival rate up to 5 years of follow-up. In a longitudinal study on conventional immediate implant placement with similar follow-up, a 97.7% implant survival rate was reported after 2 to 5 years.[33] Even though both techniques yield comparable survival rates, facial mucosal recession has been found to be inevitable when conventional immediate implants are employed.[34,35]

The intentional retention of the facial aspect of the root has been shown to minimize volumetric alterations at the implant site.[36] In an in vivo study, Hurzeler et al (2010) reported that no resorptive process could be noted on the alveolar bone in the area of the root fragment.[25] This finding is consistent with clinical observations of excellent ridge dimensional stability following retention of a buccal root fragment in the present study. The aforementioned findings can be attributed to the lack of bone remodeling because of the retention of the facial compartment of the PDL. It is well established that one of the main etiologic factors contributing to postextraction buccal plate resorption is the reduced blood supply.[9] Data from animal studies where this technique was utilized have shown that a healthy periodontium is maintained in the area of the root fragment, with a physiologic PDL existing between the bundle bone of the alveolar process and the cementum of the root fragment.[25,36] The blood supply from the maintained PDL seems to be the pivotal factor in the dimensional stability of the facial hard and soft tissues.

Previous authors have referred to this technique as "unconventional implant treatment,"[23] or "socket-shield."[36] In the present study, the term "root-membrane technique" was coined to accurately describe this procedure. Root-membrane technique is a more appropriate term because it shifts the focus of this technique to the maintenance of the root fragment. As previously mentioned, the attached PDL on the retained root fragment is the main reason why blood supply is maintained, and thus, ridge resorption is prevented.

Other authors have attempted to use bone grafts or biologic factors concomitantly with variations of the root-membrane technique to further reduce ridge resorption and facilitate bone-to-implant contact.[25,37] With the root-membrane technique, no bone grafts or other biomaterials were used. This concept is supported by recent histologic data showing that without the use of biomaterials, new bone is grown in the space between the dentin fragment and the implant.[36] Therefore, the percentage of osseointegration of implants placed using this technique does not seem to be compromised. In the present study, CBCT imaging revealed a radiolucent line at the implant-root interface that was attributed to beam hardening as, based on Baumer et al, junctional epithelium is expected to be in contact with the root fragment only in the coronal aspect, while starting from the implant shoulder the bone is found to be in direct contact between the implant and the dentin.[36]

In regard to the fate of the retained root fragment, only one patient with apical root resorption was noted in this case series. In this patient, resorption seemed to be self-arrested and did not compromise the stability of the implant. Radiographically, the resorption pit was filled with new trabecularized radiopaque tissue, consistent with the growth of new bone in the area. These findings indicate that in the infrequent case of root resorption in association with the root-membrane technique, replacement resorption may occur that can lead to so-called ankylosis of the implant.[38,39]

For natural teeth, ankylosis is an undesirable turn of events. Around implants direct contact of the implant with the bone is physiologic, and, as in the case reported in our study, does not lead to compromised implant survival. On the contrary, it may further increase bone-to-implant contact surface. Davarpanah and Szmukler-Moncler also reported a case of resorption associated with this technique.[23] In their report, the coronal aspect of the dentin showed signs of resorption that were attributed to implant overload.[23] Still, no deleterious effects on implant survival were noted. Baumer et al also raised the clinical question of what type of tissue would form if root resorption of the retained root fragment would occur.[36] The current findings demonstrated that bone healing followed the resorption of the root fragment, but the very low frequency of this complication in the present study will not allow definitive conclusions to be drawn on the type of tissue that will form should resorption of the root-membrane occur. Therefore, clinicians should be always mindful of potential resorption of the root fragment and should employ adequate means for the diagnosis and monitoring of such adverse events.

Specific protocols for radiographic monitoring of implants placed with the root-membrane technique have not been established because of the recent clinical introduction of this technique. In the present study, periapical radiographs were primarily used for the evaluation of the retained root fragments based on the recommendation of Davarpanah and Szmukler-Moncler.[23] Even though evaluation of the cervical portion of the retained root fragment is feasible with this approach, the assessment of the apical portion of the root fragment may be challenging in patients where the titanium implant superimposes on the root. In such patients, clinicians could consider the use of imaging options that allow for the three-dimensional evaluation of the root-membrane. An additional limitation of periapical radiographs is the lack of absolute reproducibility in everyday practice. Even when efforts are made for standardization, slight discrepancies in alignment may occur and should be taken into consideration during radiographic interpretation.

This article presents the largest longitudinal study on the survival of immediate implants placed adjacent to a root fragment. The present evaluation included not only ankylosed teeth, but also periodontally healthy teeth that were deemed nonrestorable, even if they were not ankylosed or fractured. Based on the current results and findings of other groups, it can be concluded that the root-membrane technique is a safe treatment modality that yields high implant success rates.[23,36,37,40] Available information from the literature reveals that there is a great potential for the widespread use of this technique. This unique improvisation seems promising by allowing dimensional stability around an implant site without the use of any adjunctive biomaterial. In addition, the dentogingival fibers that remain attached to the retained root fragment seem to increase soft tissue esthetics in the area by maintaining the mucosal zenith at a more coronal position.[37] Based on current evidence, there is significant merit for future research attempts to investigate in a controlled fashion whether the benefit from the use of this technique can establish it as the gold standard for immediate implant placement in the esthetic zone. Because successful osseointegration of implants placed with the root-membrane technique was verified in the present study, the principle outcome that ought to be evaluated in future studies is the maintenance of the gingival zenith as a result of the partial maintenance of the periodontal apparatus that leads to stability of the crestolabial tissues.

CONCLUSIONS

The intentional retention of the buccal aspect of the root with its periodontal apparatus during immediate implant placement can lead to predictable and sustainable osseointegration of implants placed in the maxillary anterior region of healthy adults.

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The authors report no conflicts of interest.

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