Single-Tooth Implants and Their Role in Preserving Remaining Teeth: A 10-Year Survival Study

George Priest, DMD*

The use of teeth as abutments for fixed and removable partial dentures can result in biologically destructive consequences. Teeth adjacent to edentulous spaces should exhibit improved prognoses if restorative trauma is to be avoided or minimized. Implants offer a method of tooth replacement without relying upon the surrounding dentition for support. This investigation evaluates implant survival and prosthetic complications of implants that replaced single missing teeth and were placed in clinical practice during a 10-year period. It further examines preoperative status and survival of teeth adjacent to these implant restorations during the same 10-year time span. Ninety-nine patients treated with 116 implants and 112 single-tooth implant prostheses in a prosthodontic practice were examined between 1988 and 1998. The purpose of this study was to evaluate the role of implants in preventing the use of intact teeth for initial support of prostheses and in avoiding the use of additional teeth as abutments upon the replacement of existing restorations. Three implants failed over a 10-year period, for a survival rate of 97.4%. Complications included the loss of 2 implant crowns, screw loosening, broken screws, cement washout, margin exposure, and porcelain fracture. Of 196 teeth adjacent to edentulous spaces, 156 (79.6%) were intact or minimally restored. Only 3 of these teeth were restored as part of initial prosthodontic therapy. Over the ensuing 10 years, only 1 tooth required a replacement restoration, and 1 tooth was extracted. Results of this patient evaluation demonstrated that implant survival over a 10-year period was favorable, with minimal prosthetic complications. Furthermore, teeth adjacent to single-tooth implants exhibited an extremely low complication rate. This report indicates that implants can be effective in preserving intact teeth in patients undergoing initial prosthodontic therapy and in preventing the use of additional teeth as abutments in patients whose existing prostheses must be replaced.
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Key words: abutment, biologic risks, dental implants, fixed partial denture, single-tooth implant, survival, tooth loss, tooth preservation

Initial placement of a dental prosthesis is rarely the end of treatment. It may be just the beginning of a potentially traumatic life span for the teeth and associated oral structures. Likewise, the cost of a newly placed prosthesis may only be the start of an ongoing financial investment. The ultimate goal of restorative dentistry is preservation of the teeth and surrounding oral structures.[1] However, this goal is not always met using traditional dental treatment methods. Instead, technical procedures related to tooth replacement sometimes contribute to biologic risks that lessen the prognosis of the abutment teeth. Avivi-Arber and Zarb[2] noted that "fixed prostheses are associated with the sacrifice of sound tooth tissue and inherent risks of pulp injury." Brantley et al[3] conducted a survey of 66 practicing dentists and reported that 70% of treatment recommendations resulted in an increased number of restored surfaces. Furthermore, the "cycle of rerestoration" that they describe leads to larger restorations with some regularity. Rerestoration and expansion of prostheses carry increased biologic risks and higher costs of dental care. Longitudinal reports indicate that prosthesis failure is common and occurs more frequently with removable prostheses than with fixed partial dentures.[4–6]

*Private Practice, Atlanta, Georgia; and Prosthodontic Mentor, Implant Innovations, Palm Beach Gardens, Florida.

Reprint requests: George Priest, DMD, 999 Peachtree Street, N.E., Suite 715, Atlanta, Georgia 30309. Fax: (404) 872-3177.

Failure of prostheses alone is not particularly alarming, but the biologic sequelae that sometimes ensue may be cause for concern. Caries, the most frequently reported cause of prosthesis failure, results in structural compromise and loss of abutment teeth.[4] Goodacre and Spolnik[7] reported that between 3% and 23% of abutment teeth require endodontics after prosthesis placement. Tooth fracture and post dislodgment compound endodontic failures.[8,9] Compromise of abutment teeth presents an additional complication upon rerestoration because teeth that have been further weakened must often support larger prostheses.

A meta-analysis of research concerning implants in partial edentulism and single-tooth replacement indicated survival rates of 93.6% and 97.5%, respectively.[10] These results are encouraging when compared with a meta-analysis of traditional fixed partial dentures conducted by Scurria et al[11] that demonstrated prosthesis survival of 69% at 15 years. In another meta-analysis of conventional fixed partial dentures, Creugers et al reported a survival rate of 74% after 15 years.[12] Lindquist and Karlsson[13] indicated a survival rate of traditional fixed partial dentures that drops significantly after approximately 10 years. At 8 years, they reported a mean success rate of 97%. In the same patient population, after 14 years, success diminished to 83%; after 20 years, it fell to 65%. Single-tooth implants should demonstrate improved longevity compared with traditional fixed partial dentures if long-term studies on implants that replace single teeth continue to reflect the high predictability already established for edentulous and partially edentulous patients.

Resin-bonded prostheses were originally intended as reversible alternatives for tooth replacement for single teeth and small edentulous spans. However, adequate retention currently depends on precise preparations that more closely resemble conventional partial coverage restorations. Resin-bonded fixed partial dentures have shown varied success rates, from only 53% over 11 months to 90% over 11 years.[4,14–17]

Implants offer considerable promise for reducing the disadvantages associated with traditional prosthodontic techniques.[2] They provide a means of support for dental prostheses without relying on the remaining teeth. Potential abutment teeth are not traumatized, and endodontic intervention is unlikely.

Contemporary implant investigations have examined the success or survival of implants and implant restorations but have not specifically evaluated their impact on the surrounding dentition. The purpose of this 10-year report of implants replacing single teeth was to evaluate the survival of implants placed in clinical practice, complications involving implant restorations, and the status of teeth adjacent to implants prior to implant placement and following definitive implant rehabilitation.

Materials and Methods

Patients receiving single-tooth implant restorations in a private prosthodontic practice in Atlanta, Georgia, between May 1988 and May 1998 were evaluated to determine their pretreatment oral status, postoperative prosthetic outcomes, and implant survival rates. This investigation included root-form implants placed consecutively by periodontists and oral surgeons ad modum Brånemark, then restored by one prosthodontist. Second-stage surgery was completed after a minimum of 3 months of healing in the mandible and 6 months in the maxilla. A single-tooth replacement was defined as a prosthesis that replaced a single tooth and was supported by 1 or 2 implants that were not adjacent to other implants.

Survival rates of implants were evaluated from the time of implant placement to the most recent periodic examination. Inclusion criteria consisted of implants that were restored and in function for at least 6 months, and patients who were examined within the last year by the treating prosthodontist or referring dentist. A standardized database was maintained for analysis throughout the study. Data from completely edentulous patients and partially edentulous patients were eliminated from the results. At a minimum, patients were evaluated prior to implant therapy, at implant placement, at implant exposure, at placement of the restoration, and 2 weeks postplacement. They were then placed on a 3-month maintenance schedule for the first year and either a 3-month or a 6-month recall schedule thereafter.

Dental histories, clinical examinations, pretreatment radiographs, and records from referring dentists were used to determine the need for tooth replacement caused by tooth loss, congenital absence, or failure of existing prostheses. Etiologies of tooth loss and types of prosthesis failure that preceded implant rehabilitation were listed. Multiple causative factors were common and were included in the results. Loss from trauma was associated with a history of avulsion or extraction in an event such as an automobile accident, fall, or gunshot wound. Tooth fracture was not related to known traumatic events. Endodontic failures

included failed conventional endodontic therapy and apicoectomies and fractured endodontically treated teeth. Clinical examinations, pretreatment radiographs, and pretreatment photographs of all patients were used to determine the status of teeth immediately adjacent to edentulous spaces prior to implant placement. Photographs included facial, occlusal, and lingual or palatal views. Teeth were described as intact if they had not been previously restored and were not in need of restoration at the time of implant placement. They were described as minimally restored if they contained small one-surface restorations that did not jeopardize the integrity of the tooth. Restored teeth included those with multisurface restorations, crowns, or retainers for existing fixed partial dentures.

Ages of participants were established at the time of initial implant surgery (Fig 1). Ages ranged from 15 to 76 years, with a mean and median of 42 years. The participants were 58 women (58.6%) and 41 men (41.4%); the mean age for women and men was 40 years and 45 years, respectively.

Ninety-nine patients treated with 116 implants and 112 single-tooth implants were examined. One hundred of the restored implants were manufactured by 3i (Implant Innovations, Palm Beach Gardens, FL), 12 were manufactured by Nobel Biocare (Nobel Biocare USA, Westmont, IL), 2 by Steri-Oss (Steri-Oss, Yorba Linda, CA), 1 by Impla-Med (Impla-Med, Sunrise, CA), and 1 by Friatec (Friatec, Irvine, CA). Most single implants were 13 mm or 15 mm in length and 3.75 mm or 5 mm in width (Figs 2a and 2b).

The author restored 107 single-tooth replacements using prosthetic components manufactured by Implant Innovations. The remaining implants were restored using components supplied by the corresponding implant manufacturer. All abutment screws were tightened to the prescribed torque using either a mechanical or an electronic torque device. Early in the study, a protocol was developed that avoided stacked restorations with small gold retention screws. Direct implant components, such as UCLA abutments (Implant Innovations), were used most of the time. Square gold abutment screws designed for 32 Ncm torque were the preferred mode of abutment retention. Initial restorations were predominantly screw-retained. As the treatment numbers progressed, more cement-retained restorations were placed and seated with a temporary cementing medium (Temp-Bond, Kerr Manufacturing, Romulus, MI) for potential retrievability. One hundred nine metal-ceramic crowns and 3 all-ceramic crowns were seated.

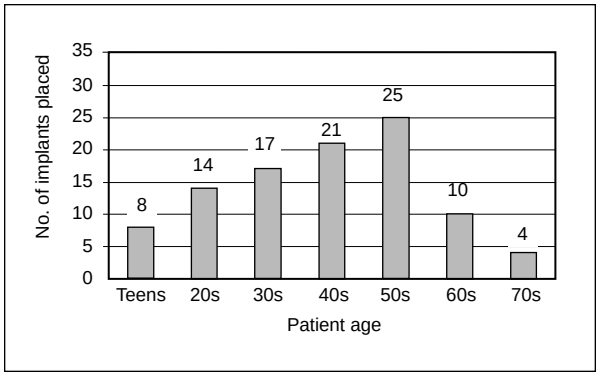

Fig 1 Ages of patients at time of single-tooth implant placement.

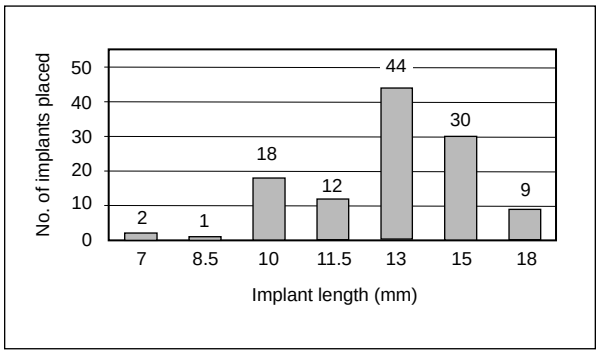

Fig 2a Lengths of single-tooth implants placed.

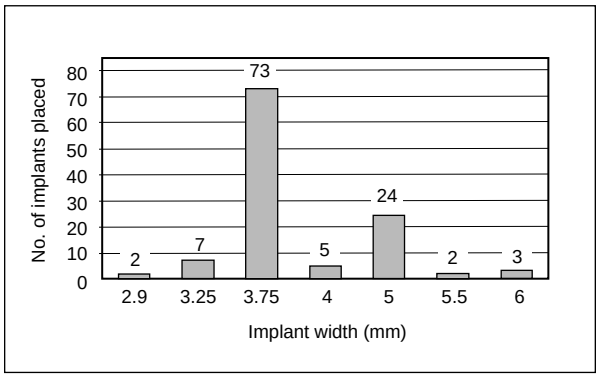

Fig 2b Widths of single-tooth implants placed.

During periodic hygiene maintenance, implants were evaluated for mobility, examined visually for marginal tissue health, and probed. Radiographs were taken prior to implant placement, immediately after implant placement, upon seating the restoration, and at least every 2 years thereafter. Margins were recorded as supragingival or subgingival upon seating, and changes in marginal status were noted at recall. Restorations were examined

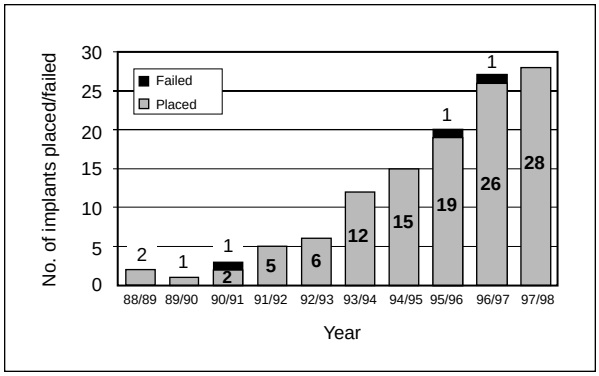

Fig 3 Single-tooth implants placed and failed, by year.

Table 1 Prosthetic Complications of Single-Tooth Implant Restorations

Complication	Frequency
Loose screw	8 (7.1%)
Cement washout	6 (5.4%)
Prosthesis lost*	2 (1.8%)
Broken screw	2 (1.8%)
Margin exposed	2 (1.8%)
Ceramic fracture/repair	1 (0.9%)
Total complications	21 (18.8%)

*One prosthesis was lost only because of implant failure.

Table 2 Reasons for Tooth Replacement

Reason for replacement	No. of subjects
Tooth loss*	85
Endodontic failure	53
Tooth fracture	24
Trauma	14
Periodontal failure	14
Resorption	6
Caries	2
Congenital absence	22
Failed fixed partial denture	1
Unknown	8

*Sum of tooth loss is greater than total because of multiple causes.

for loose screws or crowns. They were not periodically removed for examination unless a problem was suspected. Patients were questioned about esthetics, comfort, and function.

Results

Over a 10-year period, 99 patients were treated with 116 implants and 112 implant prostheses (Fig 3). From the date of implant placement, the follow-up period lasted from 6 months to 10 years, with a mean follow-up period of 30 months. Figure 3 illustrates a steady increase in single-implant use over the course of the evaluation. Eighty-three implants were placed in maxillae and 33 were placed in mandibles. Sixty-two implants replaced anterior teeth and 54 replaced posterior teeth. Three single-tooth implant replacements failed, for a survival rate of 97.4%. One 3.75 mm × 10 mm implant, which replaced a maxillary central incisor, failed during placement when an adjacent root was contacted. Loss of integration of a 3.25 mm × 13 mm lateral incisor replacement was noted at abutment connection, and a 6 mm × 13 mm implant replacement for a mandibular first molar failed 4 months after restoration. A fixed partial denture replaced the first failed implant, and the remaining 2 implants were successfully replaced. No surviving implants demonstrated detectable mobility, peri-implant pathology, or significant bone loss.

The most common prosthetic complication was screw loosening (Table 1). A greater number of cemented restorations were placed later in the series, and problems with dislodged, temporarily cemented crowns became more common than screw loosening. Two prostheses were actually lost. One loss was the result of implant failure and was not replaced. The other was redesigned and replaced after fracture of the abutment screw. Two margins on maxillary lateral incisors that were initially subgingival became exposed. Although noted, they did not present esthetic problems because of low lip lines in both patients. The porcelain on one metal ceramic crown fractured slightly and was smoothed. In 17 patients, 21 complications occurred, for a prosthetic complication rate of 18.8%.

The reasons for tooth failure and subsequent replacement are listed in Table 2. Nearly all single-tooth implant restorations were placed because of either tooth loss or congenital absence. Only one implant prosthesis replaced an existing fixed partial denture. Endodontic failure was the primary cause of tooth loss in patients missing

single teeth. It should be noted that endodontically treated teeth that fractured were included as endodontic failures. Other significant causes of tooth loss included tooth fracture, usually of previously crowned or endodontically treated teeth, periodontal failure, and trauma. Of 82 teeth that were lost prior to implant replacement, 53 (64.6%) had existing crown restorations. Maxillary lateral incisors were the most frequently replaced tooth, usually the result of congenital absence, followed by maxillary central incisors, which had been lost in most cases to trauma. The most frequently replaced mandibular tooth was the first molar (Fig 4).

During the 10 years following implant placement, additional treatment of teeth adjacent to implants was relatively low (Table 3). Results for all 112 single-tooth replacements show that 156 teeth (79.6%) of a total of 196 teeth adjacent to edentulous spaces were intact at the time of implant treatment. Three intact teeth were crowned as part of initial therapy. Two teeth served as abutments for a fixed partial denture after immediate implant failure, and one tooth was crowned for cosmetic purposes.

Forty teeth (20.4%) were previously restored or in need of restoration. Sixteen of these received crown restorations as part of initial therapy. Nine existing restorations were replaced. Seven teeth that were not previously restored were crowned; 4 because of fracture, 2 after immediate implant failure, and 1 as a result of extreme wear. Two restored teeth had previous endodontic treatment, and 2 were endodontically treated as part of initial prosthodontic therapy. Only 2 of 196 teeth adjacent to implants required any further treatment during the 10-year follow-up. One tooth received a replacement crown, and a fractured endodontically treated tooth was extracted and replaced by a single-tooth implant.

Discussion

Implant Survival. Data were not collected for patients who selected traditional treatment methods. Follow-up of a biased group undoubtedly influenced the results but does not diminish the significance of the outcome. The reported results can be considered prospective and thus more accurate than a retrospective review of patient records. However, patients in this study were not evaluated by strict parameters of success as established by Albrektsson et al[18] and Smith and Zarb.[19] Survival rates were reported instead and may be higher than actual success rates.[20] Dentists rarely scrutinize clinical outcomes with strict objective criteria used in clinical research; thus survival statistics may have more relevance for routine clinical prac-

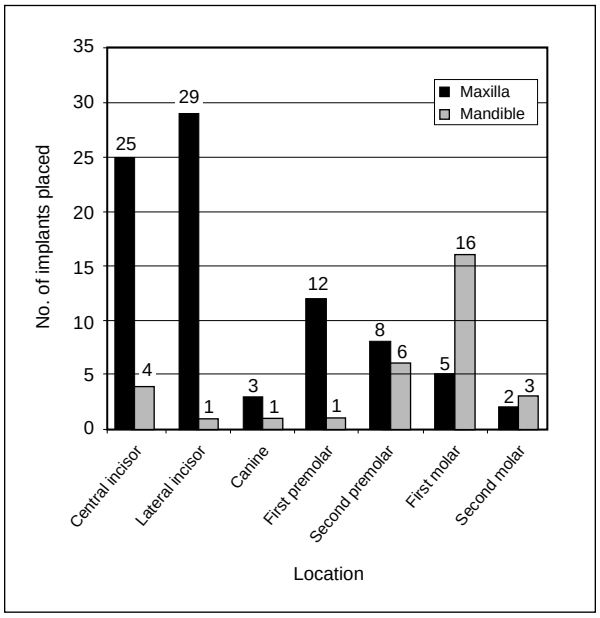

Fig 4 Position of single-tooth implants.

Table 3 Status of Teeth Adjacent to Edentulous Spaces at Implant Placement, Initial Treatment, and Follow-up Treatment Over the 10-Year Period and Status of Teeth at 10 Years

	Preoperative status	Initial treatment	Follow-up treatment	Status at 10 years
Intact or minimally restored	156 (79.6%)	3 (1.5%)	0 (0%)	153 (78.1%)
Restored/in need of restoration	40 (20.4%)	16 (12.3%)	1 (0.5%)	42 (21.4%)
Endodontically treated	2 (1.0%)	2 (1.0%)	0 (0%)	4 (2.0%)
Extracted	0 (0%)	0 (0%)	1 (0.5%)	1 (0.5%)

n = 196.

tice.[21] Evaluations of up to 9 years demonstrate successful implants and prostheses for single missing teeth.[2,22–37] The survival rates presented here are in accordance with these studies, and the results confirm that high implant longevity in clinical practice is a realistic expectation.

Prosthetic Complications. Prosthetic implant complications were low in this patient sample: 18.8% over a period of up to 10 years. Behr et al recently reported complication rates from 28.8% to 77.4% using 2 implant systems over an observation period of up to 8 years.[38] Screw loosening, the most common reported complication reported by other authors,[23,26,28–32,38,39] was the predominant complication of prostheses placed early in this study. All loose screws were either 10 Ncm gold retaining screws or 20 Ncm abutment screws. As also reported by other authors, this problem abated over time; this may be attributed to the use of more stable gold screws, which accepted increased torque and generated higher preload.[26,28,31,38] A consistently followed step in recent implant protocol for prostheses in this cohort was the use of gold abutment screws capable of 32 Ncm torque and the use of a mechanical or electronic torque device in tightening screws to the prescribed torque. Another reason for fewer complications over time could be related to the learning curve. In one 10-year retrospective study, success of single-tooth implants and prostheses dramatically improved over time.[40]

Two subgingival margins became exposed. In the majority of implant restorations, the marginal tissue response improved over time. Spontaneous papilla regeneration was a routine finding, along with some midfacial recession. These two phenomena usually contributed to scalloped, healthy-appearing gingival architecture. Jemt reported similar findings and objectively measured tissue changes in single-tooth implant replacements.[41] Papilla regeneration was noted in 80% of single-tooth implants, and recession was common in the midfacial region.

Reasons for Tooth Replacement. Tooth loss that necessitated implant replacement was most often caused by periodontal failure, endodontic failure, tooth fracture, or congenital absence. In an examination of single-tooth implants in a Finnish population, Kemppainen et al[22] found comparable results. Ekfeldt et al[26] noted that the etiology of tooth loss was primarily related to trauma in more than half of their patient sample. Engquist et al[28] and Scheller et al[36] also reported that aplasia and trauma were primary indications for implant replacement. There was a distinct age-related dichotomy in this population. All congenitally missing teeth and most teeth lost by trauma were found in patients under 35 years of age. Traditional fixed partial dentures, particularly in younger patients, carry inescapable risks. It was noted by Avivi-Arber and Zarb[2] that "the younger the patient is when a fixed prosthesis is placed, the greater the risk of tissue-dependent changes." This first group avoided initiating the potential traditional cycle of restoration by selecting implant replacements.

A second group, primarily age 40 and older, required restorations because of the failure of traditional restorative procedures. In these patients, implants prevented larger restorations and avoided trauma to additional teeth. This report supports the premise that many patients seek prosthodontic care because of complications invoked by traditional dental procedures, and intact teeth may be spared by using implant options for initial or subsequent tooth replacement. In this patient population, 79.6% of teeth adjacent to single-tooth implants were intact and otherwise not in need of restoration. Very few of these teeth required additional treatment over the ensuing 10 years. Had they served as abutments for traditional fixed partial dentures, existing observations concerning complications of fixed partial dentures indicate that additional treatment would have been much more likely.[4] These patients are exchanging the potential of biologic compromises invoked by traditional treatments for those of implant therapy. The data presented here demonstrate that potential prosthetic complications with implants may be fewer than those seen with traditional fixed partial dentures; long-term biologic trauma may also be less. This comparison has biologic and economic significance. Hess et al[42] stated that the choice of restoration should be based on a balance of cost-benefit and low risk, and implants should be used only when they provide results at least as good as those offered by conventional fixed restorations. Implant restorations may be costly initially, but high implant survival rates, coupled with a low occurrence of complications involving implant prostheses and adjacent teeth as reported here, indicate reduced trauma and a cost benefit over the long term.

Abating the Cycle. In this patient population, implants appeared to decrease biologic risks to intact teeth and thus averted initiation of the potential downward spiral of restoration for patients missing single teeth. More than 79% of teeth that would have served as abutments for traditional prostheses were intact, and most remained

unrestored. There is risk of failure with any treatment selected for tooth replacement, but failure rates alone may not be as significant as the consequences of these failures. Risks to the teeth that serve as abutments for traditional fixed and removable partial dentures may be higher than the risks associated with dental implants. Although there is the potential of biologic consequences related to the surgical placement of implants, few have been reported for single-tooth replacements.[22–37] Unless adjacent teeth are inadvertently traumatized during implant placement, the biologic risk to remaining teeth would seem to be small. This report indicates that the prognoses for remaining teeth may be improved by using implants to avoid traumatic procedures on teeth adjacent to edentulous spaces. In a retrospective study, Shugars et al[43] discovered that the restoration of posterior edentulous spaces with traditional removable prostheses or fixed partial dentures did not significantly increase the short-term survival of teeth adjacent to these spaces.

The tooth-sparing advantages of dental implants offer notable contributions to conservative methods of dentition restoration, despite the surgically invasive procedures involved. They are effective means of preserving existing teeth and supporting structures. Implants provide a predictable means of support in patients requiring single-tooth replacements, while avoiding the use of natural teeth as abutments. Originally developed as a last line of defense for edentulous patients, implants have moved to the forefront of treatment options for all degrees of partial and complete edentulism. Reluctance to use implants may stem from a reliance upon traditional treatment-planning objectives that have proven sound for many years but may need reevaluation. Although it has been deeply ingrained in dental education to save teeth at all costs, this may no longer always be desirable.[44] Lloyd has stated that the profound effects of implants on dental care are establishing new standards of performance.[45] The success of implants has led to a reexamination of traditional standards of dental care, and it has elevated these standards to higher levels.[46] Evidence of a shifting paradigm that includes the routine use of implants for tooth replacement has been reported by several authors.[47–50] High implant success and few prosthetic complications, as evidenced in this report, indicate that implant restorations may soon replace the 3-unit fixed partial denture as the primary option for single-tooth replacement.

Conclusions

Ninety-nine patients requiring single-tooth replacements were established with 116 implants and 112 implant restorations over a 10-year period. Data collected included reasons for tooth replacement, status of teeth adjacent to edentulous areas, and implant survival. Results revealed the following:

1. Three implants failed, for a survival rate of 97.4%.
2. Twenty-one implant-related prosthetic complications occurred in 17 patients.
3. Implant restorations for single missing teeth were placed primarily because of tooth loss caused by endodontic or periodontal complications, trauma, fracture, or congenital absence.
4. Of 196 teeth, 156 (79.6%) were intact or minimally restored adjacent to single-tooth implant restorations, and all but 3 remained intact throughout the 10-year period. Over the ensuing 10 years, only 2 previously restored teeth adjacent to implants required further treatment.
5. The use of implants to support dental prostheses demonstrated a tooth-preserving effect by avoiding the use of intact teeth during the initial placement of prostheses and prevented the incorporation of additional abutment teeth upon replacement of existing restorations.

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