The Longitudinal Clinical Effectiveness of Osseointegrated Dental Implants in Anterior Partially Edentulous Patients

George A. Zarb, BChD, DDS, MS, FRCD(C), Dr Odont (HC)*

Adriamne Schmitt, BSc, MSc, DDS**

Department of Prosthodontics
Implant Prosthodontics Research
Teaching and Service Unit
Faculty of Dentistry
University of Toronto
Toronto, Ontario, Canada

For many years the technique of osseointegration in the anterior part of the mouth has been used with predictable success to treat completely edentulous arches. This prospective study was begun in the mid-1980s to adapt this technique to the partially edentulous situation in this same anterior region of both the maxillae and mandible. Ninety-four implants were placed into 34 edentulous areas in 30 partially edentulous patients. Forty-seven (94%) of the 50 implants placed into maxillae and 39 (88.6%) of the 44 placed into mandibles remain in function after periods of loading ranging from 2 to 8 years (mean 4.7 years). This average success rate of 91.5% was sufficient to ensure a 100% resolution of the selected patients’ maladaptive prosthetic experiences. These results suggest that past experiences with osseointegration in the anterior of the completely edentulous mouth can be replicated in patients with anterior partial edentulism. Int J Prosthodont 1993;6:180–188.

Anterior tooth absence or loss is usually the result of congenital, traumatic, or infective events (Figs 1a and 1b). Specific information on the incidence and occurrence of partial edentulism at this site is not readily available. However, clinical experience with prosthetic management of the missing anterior dentition has proven to be a longstanding challenge. The inherent risks of aggressive tooth reduction associated with complete crown abutment coverage, the infrequent patient acceptance and tissue tolerance problems with removable partial denture therapy, and more recently the documented longitudinal shortcomings of the adhesive prosthesis (resin bonded cast metal restoration) have all underscored the fact that the ecologic influence of the traditional types of prosthetic service cannot be ignored.

The 1982 introduction of the clinical technique of osseointegration had a great impact on the discipline of prosthodontics, and much hope for its universal application was elicited. However, the accompanying euphoria and excitement tended to overshadow two compelling facts: (1) that the documented long-term success of osseointegration was limited to the anterior, or zone 1, of edentulous maxillae and mandibles (Fig 2), and (2) that while longitudinal effectiveness for five or more implant abutments has been demonstrated, this should not be automatically extrapolated to either multiple, or single, partially edentulous replacements in zone 1 or zone 2 of either arch. Put more bluntly, the specific and predictable abutment potential of abbreviated or reduced areas of osseointegration is not known. It was therefore apparent that prospective studies of diverse prescriptions of the osseointegration technique were required if the efficacy of osseointegration was to be reconcilable with its...
Multiple tooth loss in the anterior part of the dental arches may result from trauma, congenital anomalies, or infection. The resultant anterior partial edentulism poses numerous challenges that are influenced by various factors, including different amounts of circumoral activity.

Since patient treatment reports are no substitute for orderly investigation, and the harsh reality of a learning curve must be recognized with all clinical innovations, a series of Toronto prospective clinical studies was started in 1983 to test diverse applications of the technique. Patients with multiple or single missing teeth were divided according to various partially edentulous classification categories — anterior zone, posterior zone, and single tooth replacement — and were treated and monitored longitudinally.

The objective of this study was to evaluate the clinical effectiveness of two or more implants used as tooth root analogue abutments in a population of patients who were actively seeking treatment for their anterior partial edentulism.

**Materials and Methods**

The consecutively treated subjects were selected from a pool of patients who presented with missing teeth in the anterior arc and with natural tooth support in the posterior arch. Thirty patients with 34 partially edentulous arches met the inclusion and exclusion criteria for the study. Their motivation for seeking treatment was twofold: (1) maladaptive experience with a removable partial denture of varying duration (they perceived their adaptation problems as resulting from retention, stability, functional, or aesthetic reasons, and repeated prosthetic efforts had not resolved them) and (2) reluctance to have intact or quasi-intact potential abutments prepared for crown retainers, even when the partially edentulous span was not amenable to a fixed prosthetic solution.

Inclusion criteria were similar to those employed by the authors in their edentulous patient study:

1. Demonstrated maladaptive experience or unwillingness to have abutment teeth prepared for crowns
2. Ability to undergo a minor oral surgical procedure
3. Bony dimensions capable of accommodating at least a 3.75 x 10 mm Bränemark implant
4.
   5. Realistic expectations regarding aesthetic results

The decision to prescribe implant-supported prostheses also included these additional considerations:

1. There must be sufficient vertical space to accommodate the prosthetic components available together with proposed pontic and occasionally gingival analogue (labial flange) designs.
2. The ensuing occlusal load would be distributed over varying areas of both implant and natural tooth support.
The study population was composed of 30 patients, 15 men and 15 women. The mean age for the men was 40.8 years (range 18.9 to 61.6 years) and for the women was also 40.8 years (range 19.0 to 61.6 years). Four of the patients had edentulous spaces in anterior areas of both the maxillae and mandible. The reasons for tooth loss included trauma (10 patients), caries (9 patients), periodontal disease (9 patients), and congenital anomalies (2 patients).

A provisional tooth arrangement was made on diagnostic casts and used to prepare a surgical template whenever bone resorption was minimal and a critical pontic–residual ridge relationship would occur. Whenever residual ridge resorption was moder-
Osseointegration in Anterior Partially Edentulous Patients

Figs 4a to 4c: This patient also sustained a traumatic incident. He was treated with implant-supported fixed prostheses using stock prosthetic teeth and silver-palladium frameworks. Depleted residual ridge morphology permitted the use of removable prosthodontic laboratory protocol (see Table 1). The esthetic result was planned in the context of the patient's circumoral activity (see Fig 1b).

Table 1: Traditional Laboratory Protocol for Edentulous Patients

<table>
<thead>
<tr>
<th>Removable prostheses</th>
<th>Fixed prostheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensive residual ridge resorption necessitates both pontics and gingival analogues</td>
<td>Traditional fixed pontics are possible</td>
</tr>
<tr>
<td>Provisional stock tooth arrangement tried, and relation records and aesthetics confirmed</td>
<td>Template prepared from pretreatment waxup</td>
</tr>
<tr>
<td>Teeth on casts indexed</td>
<td>Metal ceramic framework is waxed up to anticipate subsequent aesthetic veneering</td>
</tr>
<tr>
<td>Framework waxed up, cast, and tried in the patient's mouth</td>
<td></td>
</tr>
<tr>
<td>Teeth waxed up to framework and tried in the patient's mouth</td>
<td></td>
</tr>
<tr>
<td>Prosthesis processed and inserted in the patient's mouth, and patient counseling given</td>
<td>Cast framework tried in the patient's mouth</td>
</tr>
<tr>
<td></td>
<td>Aesthetic veneers refined</td>
</tr>
<tr>
<td></td>
<td>Prosthesis inserted in the patient's mouth and patient counseling given</td>
</tr>
</tbody>
</table>

Prosthodontic treatment was usually initiated a few weeks following stage 2 surgery. The duration of the healing time allowed was influenced by the decision as to whether the pontics were to be ridge-lapped or would carry a labial flange. The clinical and laboratory techniques employed could be regarded as a "lateral move" of those employed for edentulous patients (Table 1). The early prostheses were made using stock prosthetic teeth and silver-palladium cast frameworks (Figs 3a to 3f and 4a to 4c). In more recent years, aesthetic and morpho-
logic dictates have necessitated the use of metal ceramic techniques (Figs 5a and 5b).

Whenever possible, a fixed prosthesis was used. If, however, the number, location, and length of the osseointegrated implants were considered inadequate, an overdenture was fabricated.

All patients were recalled 1 week after prosthesis placement and at yearly intervals thereafter. Patient compliance was very good, although some patients did not attend each recall appointment. At these recall sessions, the implant-supported prostheses were removed and each implant was radiographed and tested for mobility as well as the other success criteria outlined by Smith and Zarb (Table 2). The peri-implant tissues were monitored according to the authors' previously used protocol.

### Results

The 30 patients were treated using 94 osseointegrated implants in 19 maxillae and 15 mandibles. Eighty-six of these remain in function and are used to support 32 fixed implant-supported prostheses and 2 removable implant-supported partial overdentures. The distribution of the implants and the survival data are shown in Table 3. The mean duration of loaded function is 4.6 years with a range of 2.0 to 8.1 years (Fig 6).

### Discussion

The clinical decision to select a traditional prosthetic restoration for an anterior partially edentulous arch depends on the dentist's analysis and integration of several clinical considerations. This decision is also influenced by patient-mediated concerns, such as preference for a fixed versus a removable solution, ability to appreciate maintenance implications, and the cost of the treatment options. All of the patients in this study had experienced recent or prolonged maladaptive efforts with removable partial dentures, were reluctant to have potential abutment teeth prepared for prosthesis retention and support, and expressed a preference for a fixed prosthesis.

An implant-supported prosthesis demands simi-
Fig 6 Summary of data regarding periods of loaded service for each tissue-integrated prosthesis (TIP). As of the most recent data collection, 1 October 1992, all patients continue to wear their prostheses (31 fixed and 3 removable partial over-dentures).

Table 3 Surgical and Prosthodontic Results in 30 Patients (34 arches)

<table>
<thead>
<tr>
<th>Arches</th>
<th>Implants</th>
<th>Lost</th>
<th>“Sleepers”</th>
<th>Late loss</th>
<th>Retained in function</th>
<th>Prosthesis design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillae</td>
<td>19</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>3 (6.0%)</td>
<td>16 Fixed, 3 OD*</td>
</tr>
<tr>
<td>Mandible</td>
<td>15</td>
<td>44</td>
<td>4 (9.1%)</td>
<td>1 (2.3%)</td>
<td>0</td>
<td>15 Fixed</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>94</td>
<td>4 (4.3%)</td>
<td>1 (1.1%)</td>
<td>3 (3.2%)</td>
<td>31 Fixed, 3 OD</td>
</tr>
</tbody>
</table>

*Proposed prosthesis design for maxillae was 18 fixed and 1 overdenture (OD); late loss of an implant in two patients prompted the change to overdentures for them.

lar clinical considerations (number of teeth to be replaced, extent of resultant residual ridge resorption, status of abutment teeth, interarch space, occlusal features, aesthetics) to those of traditional treatment options (Table 4, Fig 7). However, additional features must also be considered, such as the actual number, size, location, and distribution of the osseointegrated and functionally loaded implants. All of these factors must also be analyzed in the context of quality and quantity of the proposed implant host sites.

Much of the experience required to treat the anterior arch was gleaned from previous experience with edentulous patients, given the zone 1 location of this type of partial edentulism. Consequently, it was tempting to regard this clinical endeavor as an abbreviated variation on the theme of edentulous patients' treatment with the technique. Published prospective studies strongly suggest that 5 to 6 osseointegrated implants, each 10 mm long and oriented in a semilunar fashion, are capable of carrying an 8- to 12-unit fixed prosthesis in a significant number of patients. In fact, variations have characterized the treatment planning of the vast majority of the authors' treated patients, while departures from this formula have usually led to overdenture designs. It therefore must be recognized that to date, the specific area of hoped-for osseointegration that provides predictable and indefinite support for occlusal loads transmitted via diverse prosthetic designs has been somewhat empirically determined. This observation does not detract from Brånemark’s seminal research but merely serves to remind the dentist that the entire area of partially edentulous treatment requires more than extrapolated patient treatment reports to justify safe and routine use of the osseointegration technique.

The authors, therefore, argued that a reduced number of implants (2 to 4 abutments) should be adequate to support a fixed prosthesis with a reduced occlusal table (6 pontics or less). This objective was planned for 33 out of 34 arches in this study. Whenever the edentulous span allowed for 5 or more implant abutments (as it did in 3 arches), a prosthesis with a relatively larger occlusal table was designed. However, as with edentulous patients, whenever the potential abutment area was regarded as inadequate for fixed prosthesis support,
Table 4  Traditional Treatment Choices for Anterior Partial Edentulism

<table>
<thead>
<tr>
<th>Extent of edentulous span</th>
<th>Fixed partial prosthesis</th>
<th>Removable partial prosthesis</th>
<th>Adhesive partial prosthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum of 4 teeth</td>
<td>Larger the span, greater the indication</td>
<td>Maximum of 2 teeth</td>
<td></td>
</tr>
<tr>
<td>Minimal resorption</td>
<td>Any type of resorption</td>
<td>Minimal resorption</td>
<td></td>
</tr>
<tr>
<td>Pulpal status must be assessed; coronal status not a hindrance</td>
<td>Prognostically dubious teeth can be accommodated in design</td>
<td>Optimal on all counts</td>
<td></td>
</tr>
<tr>
<td>Optimal</td>
<td>Can be compromised</td>
<td>Optimal</td>
<td></td>
</tr>
<tr>
<td>Inadequately studied; patient history studies and anecdotal reports suggest 5 to 10 years, limited by pontic span size</td>
<td>Inadequately studied; appears to be prolonged with optimal maintenance; limited by patient preference</td>
<td>Inadequately studied; promising short-term results; very limited application</td>
<td></td>
</tr>
<tr>
<td>Very high; may be expensive</td>
<td>Frequently accepted by default; cost is rarely a deterrent</td>
<td>High; cost may be regarded as expensive in a long-term maintenance context</td>
<td></td>
</tr>
</tbody>
</table>

![Clinical decision-making for implant-supported prostheses](image)

Fig 7  Clinical decision-making for implant-supported prostheses seeks to reconcile the different considerations of size and location of the edentulous space, together with other factors such as circumoral activity (see Fig 1b) and anatomic landmarks (see Fig 2).

A removable overdenture was fabricated. While this was planned for 1 patient, late implant losses in 2 patients made it necessary to place 3 overdentures.

This study sought to test the hypothesis that the proven biomechanical efficacy of osseointegration could be used to provide support for multiple tooth replacements in partially edentulous arches. All mandibular arches in this study were successfully treated with implant-supported fixed prostheses even though 4 of the 44 implants failed to osseointegrate and the unfavorable placement of one integrated implant precluded its use as an abutment. Fixed prostheses had been planned for 18 of the 19 maxillary arches. This objective was met in the 16 patients, although 1 patient sustained a late implant loss. Late implant loss in 2 patients (1 implant each) precluded a fixed design so an overdenture was fabricated. All overdenture patients reported a resolution of their previous prosthetic problems.

The success criteria proposed by Smith and Zarb (see Table 2) were employed, and the results appear to endorse the concept of implant-supported anterior prostheses as an alternative to traditional approaches. Treatment outcome satisfaction was reported by each of the 30 patients, an assertion that was reinforced at each recall appointment in response to the question posed to each patient: "Is there anything further that you would like the dentist to do for you to enhance your functional and aesthetic result?" Furthermore, the ecologic benefits derived from the treatment were self-evident in the context of documented absence of adverse changes in adjacent or supporting tissues. However, a number of important considerations have evolved in this study:

1. The success of any prosthetic treatment must be regarded as multifactorial and not based on successful osseointegration exclusively. Consequently, the outcome of implant-supported prostheses requires considerations of both the efficacy and efficiency of tooth abutment analogue performance, as well as the merits of a "lateral move" of traditional pontic design materials and techniques into this new treatment endeavor. Methods of incorporating specific implant prosthetic hardware into the overall paradigm require consideration as well. The adoption of traditional prosthodontic techniques, albeit largely empirical in nature, appeared to be adequate to satisfy patients, dentists, and technicians alike. This suggests that the traditional clinical and laboratory repertoire can be readily borrowed, given the functional and
The technique of osseointegration was prescribed for 30 patients in 34 arches with zone 1 (anterior arch) partial edentulism and a history of maladaptive prosthetic experience. The patients aesthetic effectiveness demonstrated in this study. The chronology of this study precluded the use of newer prosthodontic abutment components (angulated, aesthetic designs). Therefore, the minor but relevant aesthetic inadequacies encountered could be readily resolved today. This has proven to be a relatively minor problem, since patients are now counseled at their annual recall appointments about the possibility of revising their prostheses to rectify any concern that arose as a result of earlier-occurring limitations in prosthodontic hardware availability.

2. Occlusal design for these partially edentulous patients lends itself to relatively easy optimization. The objectives of occlusion originally proposed by Beyron (eg, natural tooth bilateral centric occlusal contact was almost always present) are quite readily/simply implemented since they often occur naturally. This frequently enables the dentist to design the occlusal load on the prosthesis in such a manner as to avoid any risk of occlusal overload. Hobo and Itoh proposed the concept of buffer spacing to compensate for the absent resiliency of the periodontal ligament attachment mechanism. Whenever the selected incisal guidance required anterior tooth contact, this was designed to ensure light contacts, which were tested with articulating paper. When this objective could not be met, special attention was given to prosthetic tooth wear changes and this was rectified at an annual recall appointment. The number of arches treated, along with the diversity of occlusal conditions encountered, do not allow for compelling conclusions regarding specific load-bearing potential for only a few implants. However, it is not unreasonable to suggest that a limited osseointegrated area of abutment support offers much scope for fixed prosthesis design given the dentist's ability to organize the occlusion to ensure a reduced implant load.

3. As the study evolved it became apparent that metal ceramic technology could afford excellent aesthetic design scope for particular morphologic situations. This approach is usually precluded when a gingival analogue or labial flange must be incorporated into a fixed prosthesis because of moderate to advanced residual ridge resorption (see Figs 3 to 5). While concerns have been expressed regarding the choice of tooth materials used, the present observations suggest that this may not have a significant bearing on the osseointegration outcome.

4. Some authors operate on the premise that partially edentulous patients treated with implants are at risk compared to similarly treated edentulous patients. This concept has resulted from the presumed conviction that periodontally involved natu-
Table 5 Published Clinical Data From Other Studies Compared to the Present Study

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of implants</th>
<th>Total no. of arches or implants**</th>
<th>No. of maxillary or mandibular implants**</th>
<th>Ossaeintegration success</th>
<th>Presumed Prosthodontic success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jemt et al (1989)**</td>
<td>Branemark</td>
<td>27**</td>
<td>18*</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>van Steenberghe et al</td>
<td>Branemark</td>
<td>128**</td>
<td>97**</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Schnitman et al (1991)**</td>
<td>Other</td>
<td>35**</td>
<td>26**</td>
<td>96%</td>
<td>100%</td>
</tr>
<tr>
<td>Present study</td>
<td>Branemark</td>
<td>34*</td>
<td>19*</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>94**</td>
<td>50**</td>
<td>91.6%</td>
<td></td>
</tr>
</tbody>
</table>

were recalled and examined annually, and prede-termined criteria were employed in an effort to ascertain treatment outcome. Ninety-two percent of all implants placed functioned successfully during the observation period of 2 to 8 years, enabling all patients to experience a satisfactory resolution of their prosthodontic problems. Within the limitations of the employed research design, it appears that osseointegrated implant-supported prostheses for anterior partial edentulism are a viable treatment modality.

Acknowledgments
The authors are indebted to Nobelpharma for a Staff Support Grant, which enabled them to carry out this prospective study. They also extend their gratitude to the many members of the Implant Prosthodontic Unit who participated in this study. Particular thanks are extended to surgical colleagues Drs Gerald Baker, Peter Birek, Tim Johnson, and George Sandor.

References