

Managing the Posterior Mandible of Partially Edentulous Patients with Short, Porous-Surfaced Dental Implants: Early Data from a Clinical Trial

Douglas Deporter, DDS¹/Robert M. Pilliar, BSc, PhD¹/Reynaldo Todescan, DDS, PhD²/
Philip Watson, DDS, MScD¹/Michael Pharoah, DDS, MSc¹

Forty-eight Endopore dental implants were placed in the posterior mandibles of 24 partially edentulous patients. Seventeen of these implants replaced premolar teeth, while 31 replaced molars. Only 7-mm and 9-mm implants were used, and the majority of prosthetic restorations (83%) were single crowns. After a mean functional time of 32.6 months (range, 8.2 to 50.3 months), the implant survival rate was 100% and assessment of available radiographic data showed minimal to no crestal bone loss. (INT J ORAL MAXILLOFAC IMPLANTS 2001;16:653–658)

Key words: *clinical trial, porous-surfaced dental implant, posterior mandible, surface treatments*

The posterior regions of the dental arches are generally considered to be less favorable than anterior regions for the successful use of endosseous root-form dental implants.^{1–7} Posterior regions generally have less available bone height and less favorable bone quality, while at the same time are exposed to greater occlusal loads than anterior regions of the mouth.^{8–10} Thus, in the zones where greater implant surface area—generally achieved by using longer implant lengths—is indicated to increase bone-to-implant surface contact and optimize stress transfer from implant to bone, it is often only possible to use short implants. This situation has created a dilemma for clinicians and patients, since it is well known that short implants (ie, < 10

mm in the mandible or < 13 mm in the maxilla) have a much higher failure rate.^{1,5,11}

Recent work has focused on increasing the surface area of dental implants by using wider-diameter implants^{12–14} where anatomically possible and/or by altering their surface characteristics. Methods to increase the surface area of a machined dental implant core include surface treatments such as blasting with a variety of particles, acid etching, plasma spraying, or adding a sintered, porous surface layer. A review of these types of implant surface configurations has recently been published.¹⁵ All of these approaches increase surface area by creating surface irregularities, such as depressions and/or protrusions of varying dimensions, depending on the process(es) used. The addition of a sintered, porous surface layer may have the added advantage of creating a 3-dimensional surface porosity through sinter bonding of 2 to 3 layers of metal powder particles of appropriate size. This allows for implant fixation by actual bone ingrowth into this surface.^{16–18} Human clinical trials with a sintered porous-surfaced dental implant have confirmed its successful application in short lengths in a variety of treatment applications.^{19–21} The results of a further trial reported here provide more support for this conclusion.

¹Professor, University of Toronto, Faculty of Dentistry, Toronto, Canada.

²Assistant Professor, University of Toronto, Faculty of Dentistry, Toronto, Canada.

Reprint requests: Dr D. A. Deporter, University of Toronto, Faculty of Dentistry, 124 Edward Street, Toronto, Ontario, Canada M5G 1G6. E-mail: douglas.deporter@utoronto.ca



Fig 1 Implant models used in the study patients. (Left to right) Wide-body 7 mm long; regular-diameter 7 mm long; 9-mm "mini" implant; and regular-diameter 9 mm long.

MATERIALS AND METHODS

The patients who participated in this University Clinic-based trial included 8 males and 16 females with a mean age of 49.6 years (range 20 to 72 years), each of whom required 1 or more endosseous dental implants and an implant-supported fixed restoration in the posterior mandible. A total of 48 implants were placed in 24 consecutively treated patients. All patients claimed to currently be nonsmokers and in good general health. Each was given a detailed oral and written description of the risks and benefits of the proposed treatment and signed a consent-to-treat agreement.

Pretreatment records included a medical history, a routine full-mouth series of long-cone periapical radiographs, and, if indicated, linear tomographs of the site(s) intended for implant placement. Diagnostic casts were made and a complete dental and periodontal assessment undertaken. Patients with detectable periodontal disease were first treated for this condition.^{22,23} The implants used were Endopore (Innova, Toronto, Canada) and were of 2 lengths (7 mm, $n = 32$, or 9 mm, $n = 16$) and 3 different diameters (3.5, 4.1, or 5.0 mm) (Fig 1). No formal assessment of bone quality was made either before or at the time of implant placement.

The surgical protocol used was as previously reported.²⁰ Patients were asked to rinse with 0.12% chlorhexidine gluconate for 45 seconds twice daily for 3 to 5 days prior to surgery, and to continue for 7 days following surgery. Antibiotic prophylaxis (amoxicillin, 500 mg every 8 hours for 7 days starting 24 hours before surgery) was also prescribed.²⁴ All implants were placed using a 2-stage surgical approach, and after an initial healing interval of 3 months, the healed sites were reentered and tempo-

rarily healing abutments connected to all implants. One month later, impressions were made and prosthodontic restoration begun.

Prosthodontic Procedures

At reentry surgery, healing abutments were connected to each implant and left in situ for approximately 4 weeks to allow soft tissue healing before impression making. For all implants, impressions were made at the implant level employing a closed-tray technique. Transfer copings (Innova), custom-made trays, and either polyether (Polyjel NF, Dentsply International, York, PA) or polyvinyl siloxane (PolySil, Medtech AG, Basle, Switzerland) impression materials were used.

Porcelain-fused-to-metal crowns were fabricated using UCLA-type abutments that were subsequently cast in gold alloy (Olympia, JF Jelenko, Armonk, NY). The restorations were made retrievable by providing an access hole in the occlusal surface for a retaining screw. Occlusal contacts were adjusted at maximum bite force, and at the time of final placement or reinsertion, the retaining screws were secured using a torquing wrench (Attachments International, San Mateo, CA) set at 30 Ncm.

Radiographic Assessment

The authors intended to collect periapical radiographs of all implants in this group of patients at baseline (1 month after seating of the definitive prosthesis), and after 6 months, 1 year, and 2 years of function. The plan was to collect these radiographs using a stainless steel radiographic filmholder developed for a concurrent prospective clinical trial of the same implant device in the maxilla. To use this device, it is first necessary to remove the implant prosthesis and abutment and to connect the filmholder directly to the implant by means of a separate screw and various metal spacers. However, this procedure was impractical for use in the posterior mandible because of the risk of damaging the internal threads of the implant roots. Therefore, this plan was abandoned and the radiographs were exposed without removing the prostheses, using customized acrylic resin occlusal templates and a standard long-cone paralleling technique.

All radiographs were exposed using the same calibrated X-ray machine and developed manually in batches using fresh solutions. They were masked and viewed in a darkened room by one radiologist. Measurements of the position of the alveolar crest relative to the machined surface/porous surface junction of the implant root component on the mesial and distal of each implant were made with a reticule and 6 \times magnification.

Table 1 Distribution of Implants Used

Implant model	No. placed	No. failed
7 mm long × 4.1 mm diameter	18	0
7 mm long × 5.0 mm diameter	14	0
9 mm long × 4.1 mm diameter	14	0
9 mm long × 3.5 mm diameter	2	0
Total	48	0

Table 2 Distribution of Implant Sites by Tooth Location

Tooth location	n	Percent
First premolar	4	8.3
Second premolar	13	27.1
First molar	28	58.3
Second molar	3	6.3

Table 3 Life Table Analysis of All Implants

Time after onset of function (months)	Implants at start of interval	Failures	Interval failure rate	Cumulative survival rate (%)
0 to 12	48	0	0	100
13 to 24	43	0	0	100
25 to 36	30	0	0	100
37 to 48	15	0	0	100

Statistical Assessments

Implant performance was determined using life table analysis.²⁵ The radiographic data were from 48 implants in 24 patients, and therefore the implants were not independent. Accordingly, multivariate analyses of variance employing mixed models were used to account for both between- and within-person variation.²⁶ The mesial and distal bone measurements were first assessed separately for changes in bone height with time, ie, between sequential radiographs. Following this, average bone loss data for each implant (ie, averaging the mesial and distal bone height values for each implant) between examination intervals were computed and assessed for changes in sequential radiographs.

RESULTS

All 48 implants placed in the 24 patients in this trial group became successfully integrated and supported restorations. The implants used are shown in Table 1 and were either 7 mm or 9 mm long (mean, 7.7 mm). Seventeen were used to replace premolars and 31 were used to replace molars, including 3 for second molars (Table 2). Nine patients received single implants, while 15 patients received more than 1 implant. When more than 1 implant was used to restore function in a region, 31 of these implants were restored as individual crowns (ie, were not splinted together), while the remaining 8 implants were splinted. Thus, 83% (40 of the 48) of the prosthetic restorations were individual crowns.

The mean functional time of these implants at the time of preparation of this report was 32.6 months, with a range of 8.2 to 50.3 months. A life table analysis for the implants is shown in Table 3.

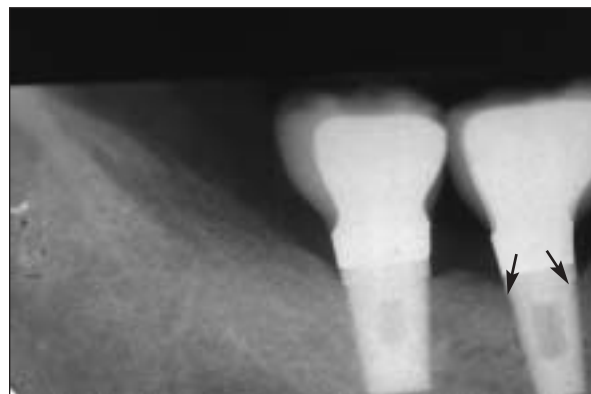
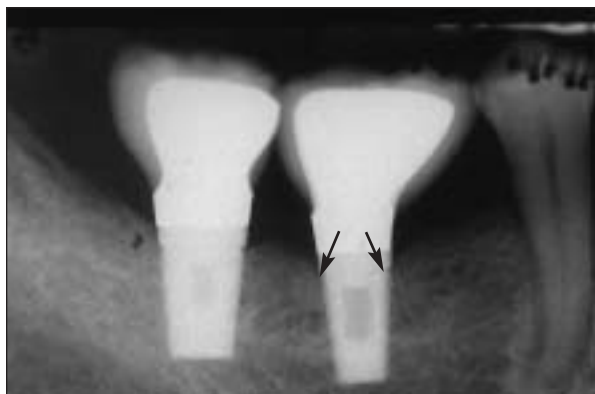
Radiographic Findings

At the time of this report, radiographic data were available for 29 of 48 implants after 6 months of function, 31 implants after 1 year, 19 implants after 2 years, and 15 implants after 3 years of function. Missing radiographs were either not obtained or rejected by the radiologist as not being accurate enough to be read. In addition, only those implants for which radiographs were available at the beginning and the end of a given interval could be used to assess changes in bone level, and this further reduced the number of films that could be used for the analysis. Results of these incomplete crestal bone measurements are given in Table 4, while sample radiographs for a patient whose implants had been in function for more than 2 years are shown in Figs 2a and 2b. The mean bone loss data for all times in function indicated no statistically significant change from baseline. For example, between baseline and 6 months, there was a mean loss of 0.03 mm, which is clinically insignificant. Between 6 months and 1 year and between 1 year and 2 years, there appeared to be a mean gain in bone height of 0.12 mm, but this could easily represent measurement error. The only fair conclusion from these observations would be that the crestal bone levels appear to be stable.

Table 4 Within-Person Bone Loss (in mm) Between Consecutive Measurements

Time interval error (months)	n	Lower 95% limit	Sample mean	Upper 95% limit	Standard
0 to 6	24	+0.10	-0.03	-0.15	0.06
7 to 12	25	+0.24	+0.13	+0.03	0.05
13 to 24	10	+0.47	+0.12	-0.23	0.11
25 to 36	15	+0.17	-0.13	-0.43	0.12

n denotes number of implants with radiographic data at both the beginning and end of the interval, enabling the difference to be calculated. + = bone gain.



Figs 2a and 2b Sample radiographs of a patient (left) at baseline and (right) after 2 years of continuous function. The arrows denote the machined surface/porous surface junction. The crestal bone level has remained unchanged over the 2-year period.

DISCUSSION

A number of investigators have reported on the use of root-form endosseous dental implants in the posterior mandible. For example, Nevins and Langer³ presented retrospective data for 551 Brånemark System implants (Nobel Biocare, Göteborg, Sweden) placed in this area for 200 patients. The mean implant length used was 10.8 mm, and of the 25 failures, all but 3 (two 13-mm implants and one 18-mm implant) were either 7 or 10 mm in length. At the time of the report, the majority of implants had been in function for 3 to 5 years and the overall survival rate was stated to be 95.5%. Zarb and Schmitt⁶ reported the outcome of a prospective study in which 64 Brånemark System implants were used with fixed prostheses to restore 29 posterior mandibular sites in an unstated number of patients. The actual implant lengths were not given, but, as stated by the authors, the majority of implants used had lengths of 10 mm or more. At the time of the report, the prostheses had been in function for periods ranging from 2.6 to 7.4 years, and the implant survival rate was reported as 92.2%.

Results in the posterior mandible for other endosseous dental implant designs have not been as favorable. For example, Block and coworkers²⁷ followed the progress of 443 hydroxyapatite- (HA) coated cylindrical press-fit implants (Integral, Calicitek, Carlsbad, CA; 8 to 15 mm long) placed in 174 patients. At the time of the report, 233 implants had been in function for 5 or more years, and 80 of these had been monitored for more than 8 years. The data were presented as life table analyses in 2 ways: as implant survival alone and as implant survival in combination with implants deemed failures by virtue of the fact that they had lost greater than 2.5 mm of crestal bone as detected in radiographs. The cumulative 10-year survival rate based on implant loss only was 79%, but this decreased to 64.6% when implants deemed failures on the basis of excessive crestal bone loss were included. Both of these survival figures would be considered unsatisfactory if the criteria of Albrektsson and associates²⁸ were applied. The greatest number of failures in Block and coworkers' report occurred in the second molar location, and the authors attributed this to mechanical overload.²⁷ They stated that the surface

area of a 4-mm-diameter, 8- or 10-mm-long cylindrical implant is less than that of a second molar, and this fact, in conjunction with the low bone density often found in the posterior mandible and the high occlusal forces generally experienced in this site, would predispose this implant design to failure.

The data presented in the current report for porous-surfaced (Endopore) dental implants are encouraging, especially given the short implant lengths used (the majority, ie, two thirds, were only 7 mm long) and the fact that the majority (83%) were not splinted. To date, with a mean functional time of 32.6 months, the 48 implants placed into the posterior mandible of 24 consecutively treated patients have been 100% successful using established criteria,²⁸ and patterns of minimal crestal bone loss are similar to those seen in other partially edentulous sites treated with the same implant^{21,22} and in the edentulous anterior mandible.²⁰ Of the 48 implants included in this group, 31 were used to replace molar teeth, and 27 of these were restored with individual (ie, nonsplinted) crowns with an occlusal table approaching that of a normal mandibular molar tooth. This compares well with reports from others on the performance of other implant systems in replacing single molar teeth. For example, Schwartz-Arad and coworkers²⁹ reported retrospective data on 55 consecutively treated patients who received 78 implants, 75 of which were used to replace single molar teeth in the posterior mandible. The implants used were either HA-coated, press-fit cylinders or HA-coated or acid-etched threaded titanium implants. The mean implant length used was 12.9 mm, with a mean diameter of 3.89 mm. Nevertheless, the cumulative survival rate after an average functional time of 24 months was only 92.3%. The majority of the failures were acid-etched threaded implants of diameter 3.75 mm. These results may have prompted some clinicians to suggest using wide-diameter (ie, 5.0 mm or greater) implants or even 2 threaded implants to support a single molar crown in the mandible.^{30,31} On the other hand, Becker and Becker³² reported retrospective data on a group of 17 Brånemark System implants used to replace single mandibular molars and reported 100% success after 2 years of function. The implants used in their patient group had a minimum length of 10 mm with a mean of 12.7 mm (ie, 5 mm longer than the mean length used in the present study).

The early favorable experience in the posterior mandible as reported here can be at least partially explained by the large surface area provided by the implant design.¹⁵ Estimates of the surface areas of this implant using simple geometric models suggest that the real surface area of sintered porous-surfaced

implants is about 3 to 4 times that of machined, threaded implants of equal length. Probably of greater significance than surface area, however, is the fact that porous-surfaced implants allow for a substantial 3-dimensional mechanical interlock to develop at the bone-to-implant interface by bone ingrowth.^{17,18,33} This interface can effectively resist not only interfacial shear forces, but also tensile forces created particularly by transverse force components of occlusal loading, and this feature is unique to a sintered, porous-surfaced geometry. As a result, there may be a more uniform distribution of stresses within bone supporting and surrounding a porous-surfaced implant³⁴ and thus avoidance of stress-related microdamage to bone that could result in bone resorption and fibrous tissue ingrowth at the interface, subsequent micromovement, and ultimately implant failure resulting from mechanical overloading. It may also be that the local stress field resulting within the porous surface zone is more conducive to new bone formation. This possibility has been investigated recently using porous-surfaced implants placed in rabbit femoral condyle sites³⁵ with a finite element study. The results supported the hypothesis that the local mechanical environment within the porous region promoted earlier bone formation than, for example, in implants with a titanium plasma-sprayed surface geometry.

SUMMARY

The results of the present investigation indicate that short (ie, 7 or 9 mm long) dental implants with a sintered porous surface geometry can be suitable for restoring edentulous spaces, including single molar teeth, in the posterior mandible. In a group of 24 consecutively treated patients with 48 implants, there were no implant failures after a mean functional time of 32.6 months, while available radiographic measurements indicated little to no crestal bone loss. The routine use of such implants in the posterior mandible, as in other locations in the partially edentulous patient,^{21,22} could greatly simplify the management of patients with minimal bone height in this location.

ACKNOWLEDGMENTS

The authors wish to thank Karen Nardini, Nancy Valiquette, and Caroline Chu for their valuable administrative assistance. Partial funding was provided by Innova Corporation, Toronto, Canada.

REFERENCES

1. Van Steenberghe D, Lekholm U, Bolender C, et al. The applicability of osseointegrated oral implants in the rehabilitation of partial edentulism. A prospective multicenter study on 558 fixtures. *Int J Oral Maxillofac Implants* 1990;5:272-281.
2. Bahat O. Treatment planning and placement of implants in the posterior maxillae: Report of 732 consecutive Nobelpharma implants. *Int J Oral Maxillofac Implants* 1993;8:151-161.
3. Nevins M, Langer B. The successful application of osseointegrated implants to the posterior jaw: A long-term retrospective study. *Int J Oral Maxillofac Implants* 1993;8:428-432.
4. Haas R, Mensdorff-Pouilly N, Mailath G, Watzek G. Survival of 1,920 IMZ implants followed for up to 100 months. *Int J Oral Maxillofac Implants* 1996;11:581-588.
5. Lazzara R, Siddiqui AA, Binon P, et al. Retrospective multicenter analysis of 3i endosseous dental implants placed over a five-year period. *Clin Oral Implants Res* 1996;7:73-83.
6. Zarb G, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants in posterior partially edentulous patients. *Int J Prosthodont* 1993;6:189-196.
7. Scurria MS, Morgan V, Guckes AD, Li S, Koch G. Prognostic variables associated with implant failure: A retrospective effectiveness study. *Int J Oral Maxillofac Implants* 1998;13:400-406.
8. Book K, Karlsson S, Jemt T. Functional adaptation to full arch fixed prostheses supported by osseointegrated implants in edentulous mandible. *Int J Oral Maxillofac Implants* 1992;3:17-21.
9. Esposito M, Hirsch J-M, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. II. Etiopathogenesis. *Eur J Oral Sci* 1998;106:721-764.
10. Taylor TD, Agar JR, Vogiatzi T. Implant prosthodontics: Current perspectives and future directions. *Int J Oral Maxillofac Implants* 2000;15:66-75.
11. Wyatt C, Zarb G. Treatment outcomes of patients with implant-supported fixed partial prostheses. *Int J Oral Maxillofac Implants* 1998;13:204-211.
12. Langer B, Langer L, Hermann I, Jorneus L. The wide fixture: A solution for special bone situations and a rescue for the compromised implant. Part I. *Int J Oral Maxillofac Implants* 1993;8:400-408.
13. Graves SL, Jansen CE, Siddiqui AA, Beaty PE. Wide-diameter implants: Indications, considerations and preliminary results over a two-year period. *Aust Prosthodont J* 1994;8:31-37.
14. Lazzara R. Criteria for implant selection: Surgical and prosthetic considerations. *Pract Periodontics Aesthet Dent* 1994;7:55-62.
15. Pilliar RM. Overview of surface variability of metallic endosseous dental implants: Textured and porous surface-structured designs. *Implant Dent* 1998;7:305-314.
16. Deporter DA, Watson PA, Pilliar RM, Chipman M, Valiquette N. A histological comparison in the dog of porous-surfaced vs threaded dental implants. *J Dent Res* 1990;69:1138-1145.
17. Pilliar RM. Dental implants: Materials and design. *J Can Dent Assoc* 1990;56:857-861.
18. Pilliar RM. Porous-surfaced metallic implants for orthopedic applications. *J Biomed Mater Res* 1987;21(A1):1-33.
19. Deporter DA, Watson P, Pharoah M, Levy D, Todescan R. Five- to six-year results of a prospective clinical trial using the Endopore dental implant and a mandibular overdenture. *Clin Oral Implants Res* 1999;10:95-102.
20. Deporter DA, Todescan R, Watson PA, Pharoah M, Levy D, Nardini K. Use of the Endopore dental implant to restore single teeth in the maxilla: Protocol and early results. *Int J Oral Maxillofac Implants* 1998;13:263-272.
21. Deporter DA, Todescan R, Caudry S. Simplifying management of the posterior maxilla using short, porous-surfaced dental implants and simultaneous indirect sinus elevation. *Int J Periodontics Restorative Dent* 2000;20:477-485.
22. Papaioannou W, Quirynen M, van Steenberghe D. The influence of periodontitis on the subgingival flora around implants in partially edentulous patients. *Clin Oral Implants Res* 1996;7:405-409.
23. Brägger U, Burgin W, Hämmerle CHF, Lang NP. Associations between clinical parameters assessed around implants and teeth. *Clin Oral Implants Res* 1997;8:412-421.
24. Dent CD, Olson JW, Farish SE, et al. The influence of preoperative antibiotics on success of endosseous implants up to and including Stage II surgery: A study of 2,641 implants. *J Oral Maxillofac Surg* 1997;55:19-24.
25. Colton T. Longitudinal studies and the use of the life table. In: Colton T (ed). *Statistics in Medicine*. Boston: Little, Brown & Co, 1974:241-249.
26. SAS/STAT Software: Changes and Enhancements Through Release 6.11. Cary, NC: SAS Institute, 1996.
27. Block MS, Gardiner D, Kent JN, Misiek DJ, Finger IM, Guerra L. Hydroxyapatite-coated cylindrical implants in the posterior mandible: 10-year observations. *Int J Oral Maxillofac Implants* 1996;11:626-633.
28. Albrektsson T, Zarb G, Worthington P, Eriksson A. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986;1:11-25.
29. Schwartz-Arad D, Samet N, Samet N. Single tooth replacement of missing molars: A retrospective study of 78 implants. *J Periodontol* 1999;70:449-454.
30. Bahat O, Handelsman M. Use of wide implants and double implants in the posterior jaw: A clinical report. *Int J Oral Maxillofac Implants* 1996;11:379-386.
31. Balshi TJ, Hernandez RE, Pryszyk MC, Rangert B. A comparative study of one implant versus two replacing a single molar. *Int J Oral Maxillofac Implants* 1996;11:372-378.
32. Becker W, Becker B. Replacement of maxillary and mandibular molars with single endosseous implant restorations: A retrospective study. *J Prosthet Dent* 1995;74:51-55.
33. Pilliar RM, Deporter DA, Watson PA, Valiquette N. Dental implant design: Effect on bone remodelling. *J Biomed Mater Res* 1991;25:467-483.
34. Vaillancourt H, Pilliar RM, McCammond D. Factors affecting crestal bone loss with dental implants partially covered with a porous coating: A finite element analysis. *Int J Oral Maxillofac Implants* 1996;11:351-359.
35. Simmons CA, Valiquette N, Pilliar RM. Osseointegration of sintered porous-surfaced and plasma-spray-coated implants: An animal model study of early post-implantation healing response and mechanical stability. *J Biomed Mater Res* 1999;47:127-138.