Osseointegration of sintered porous-surfaced and plasma spray–coated implants: An animal model study of early postimplantation healing response and mechanical stability

Craig A. Simmons, Nancy Valiquette, Robert M. Pilliar
Institute of Biomaterials and Biomedical Engineering, University of Toronto, 170 College Street, Toronto, Ontario M5S 3E3, Canada

Received 17 November 1998; revised 8 February 1999; accepted 25 February 1999

Abstract: The osseointegration and long-term success of bone-interfacing implants are dependent on mechanical stability of the implant relative to host bone during the early healing period. The geometric design of an implant surface may play an important role in affecting early implant stabilization, possibly by influencing tissue healing dynamics. In this study, we compared the early tissue healing response and resulting implant stability for two surface designs by characterizing the histological and mechanical properties of the healing tissue around Ti6Al4V sintered porous-surfaced and Ti plasma-sprayed implants. The implants were inserted transversely in rabbit femoral condyles and evaluated at 0, 4, 8, and 16 days postimplantation. At 4 and 8 days after implantation, the early healing tissue (fibrin and collagenous matrix) was more extensively integrated with the three-dimensional interconnected structure of the sintered porous surface than with the irregular geometry of the plasma-sprayed coating. In addition, histological examination indicated that initial matrix mineralization leading to osseointegration occurred more rapidly with the porous-surfaced implants. The more extensive tissue integration and more rapid matrix mineralization with the porous-surfaced implants were reflected in the mechanical test data, which demonstrated greater attachment strength and interfacial stiffness for the porous-surfaced implants 4 and 8 days postimplantation ($p < .05$). Sixteen days after implantation, both implant designs were osseointegrated and had comparable attachment characteristics. These data demonstrate that appropriate surface design selection can improve early implant stability and induce an accelerated healing response, thereby improving the potential for implant osseointegration. © 1999 John Wiley & Sons, Inc. J Biomed Mater Res, 47, 127–138, 1999.

Key words: osseointegration; implant stability; implant surface design; porous surfaced; plasma sprayed

INTRODUCTION

All load-bearing, bone-interfacing implants currently used in orthopedics and dentistry are intended to become rigidly secured in the host bone site. This condition, commonly referred to as “functional osseointegration”, is achieved by mechanical interlock of implant within bone. Mechanical interlock requires implantation using appropriate surgical placement methods to ensure an initial snug fit in prepared sites and judicious postimplantation patient rehabilitation to limit relative movements at the bone–implant interface, thereby allowing bone formation up to the implant surface. Eventual mechanical interlock or interdigitation of bone with implant surface features is responsible for allowing forces to be transferred between implant and bone while maintaining the desired implant stability. It is this condition of mechanical stability that is inferred by “functional osseointegration.”

With dental implants, where axial symmetry is possible, threaded screw-shaped implants have proved effective for achieving secure implant fixation within mandibular and maxillary sites. The threads are representative of macroscopic surface features that allow mechanical interlocking of implant within bone. Even for these designs, a minimum nonfunctional period is used to allow formation of bone in very close apposition to the implant surface prior to functional forces being applied. There has been speculation that microscopic (submicron- to micron-sized) surface features resulting from machining of threads may further contribute to mechanical interlock. Some implant manufacturers have introduced chemical etching, mechanical grit-blasting, or both processes to develop microscopic surface textures (with dimensions of submicron to tens of microns) for the purpose of achieving more effective, and possibly more rapid rigid implant fixa-
tion through bony interlock with these features.\textsuperscript{3} The effect of such surface textures on osteoconductivity and, hence, rate of bone adaptation to an implant remains a topic of current research.\textsuperscript{4,5}

Other implant surface designs are used extensively for forming bone-interfacing press-fit endosseous dental implant components\textsuperscript{6} and cementless orthopedic joint replacement devices.\textsuperscript{7} Plasma-sprayed Ti implants and porous-surfaced implants with either Ti alloy or Co-based alloy surface zones formed by sintering represent two such common designs. For all bone-interfacing applications, the question of whether certain designs offer advantages over others in terms of rate and reliability of osseointegration for various implant site conditions is of prime importance for the design of more effective implants.

There have been limited studies addressing this issue directly through comparison of implant performance \textit{in vivo}. Studies by Maniatopoulos et al.\textsuperscript{8} indicated that significant differences did occur for threaded versus sintered porous-surfaced endosseous endodontic implants subjected to early loading resulting in limited relative movement. The threaded implants displayed better initial stability because of mechanical anchorage resulting from thread-bone interlock versus the initial frictional resistance with the press-fit porous-surfaced implants. After 3 and 6 months of function, however, the porous-surfaced implants displayed secure fixation because of bone ingrowth while the threaded implants progressively loosened as a thick fibrous tissue encapsulating layer developed. Thomas and Cook\textsuperscript{9} compared press-fit implants with grit-blasted and polished surfaces and demonstrated greater bone apposition and push-out strength for the grit-blasted implants 32 weeks postimplantation. Buser et al.\textsuperscript{10} also found a positive correlation between increasing surface roughness (6–50 μm) and bone–implant contact 3 and 6 weeks postimplantation for press-fit implants. The same group demonstrated that sand-blasted, acid-etched titanium implants had significantly greater bone apposition than titanium plasma-sprayed implants 3–15 months postimplantation.\textsuperscript{11} Comparison of plasma-sprayed and sintered porous-surfaced implant response has been limited to studies reported by Luckey et al.\textsuperscript{12} and Friedman et al.\textsuperscript{13} The study by Luckey et al.\textsuperscript{12} suggested that press-fit CoCr plasma-sprayed implants yielded higher interface shear strengths than CoCr porous-surfaced implants after 16 weeks of implantation in cancellous bone sites. Conversely, Friedman et al.\textsuperscript{13} showed CoCr plasma-sprayed implants to have significantly lower bone apposition and shear strengths than CoCr porous-surfaced implants 6 and 12 weeks postimplantation.

The results of all of these studies suggest that the quality of implant osseointegration and stability is dependent in part on the geometric surface design. However, the role of implant surface design in affecting early tissue healing and implant stability cannot be determined directly from observations made several weeks postimplantation after osseointegration and bone remodeling have occurred. The issue of early healing response (i.e., within the premineralization period) next to different implant designs and the mechanical characterization of the repair/regeneration tissues formed within the implant–host bone interface zone (IZ) has not yet been addressed to the best of our knowledge.

The objective of this study was to investigate the histological characteristics and healing dynamics of the IZ tissues formed in the early postimplantation period and to determine the resulting early mechanical stability of different implant surface designs. Our studies focused on a comparison of two types of press-fit and cementless (as defined for orthopedic applications) implant designs: (a) Ti6Al4V implants with a sintered Ti6Al4V porous surface region (incorporating the features of porous-surfaced endosseous dental implants); and (b) Ti6Al4V implants with a Ti plasma-sprayed coating (as used for dental implant and orthopedic implant fabrication). The implants were placed transversely in femoral condylar sites in rabbits for prescribed periods of 0, 4, 8, and 16 days.

MATERIALS AND METHODS

Implants

The implants used in this study were similar in shape and appearance to an endosseous dental implant root component developed and studied by our group.\textsuperscript{14–17} The implants were 9 mm long, had a truncated conical (tapered) shape having a taper angle of approximately 5° and a maximum coronal diameter of 4.1 mm, and were internally threaded. The coronal 1 mm of the implants had a smooth machined surface (Fig. 1).

The implants, as noted previously, were fabricated with one of two bone-interfacing surface geometries: a sintered porous-structured surface or a plasma-sprayed surface. The porous surface was created by sintering Ti6Al4V particles 45–150 μm in diameter (−100/+325 mesh) to a machined Ti6Al4V substrate (Innova Corp., Toronto, Ontario, Canada). As described elsewhere,\textsuperscript{7} sintering was achieved in a high-vacuum furnace (<10⁻⁵ torr) at a temperature of 1250°C for approximately 1 h. The resulting porous structure was approximately 300 μm thick and consisted of two to three particle layers bonded to each other and the substrate. This treatment produced pore sizes in the range of 50–200 μm, a volume porosity of 35–40%, and a surface region with a three-dimensional interconnected porosity (Fig. 2a).

The plasma-sprayed implants were produced by application of a titanium plasma spray coating to a machined Ti6Al4V substrate (Hitemco Medical Applications, Old Bethpage, NY). The plasma-sprayed layer was approxi-
mately 30–40 μm thick. This treatment produced a rough, irregular surface with some porosity (approximately 5 vol%). The pores within the layer were more or less isolated and did not form an interconnected network of pores and channels as observed with the sintered porous surface structure. However, the plasma-sprayed surface did possess regions with undercuts and intrusions that permitted interdigitation and mechanical interlock with tissue [Fig. 2(b)].

Surgical procedure

Canadian Council on Animal Care guidelines\(^{18}\) for the care and use of laboratory animals were observed in this study. The implants were placed transversely in the medial femoral condyles of mature (4–4.5-kg) New Zealand White rabbits. The rabbits were anesthetized by induction with ketamine HCl and xylazine, and then maintained with Halothane via inhalation. The implants were placed in the flattest region of the medial surface, midway between the anterior and posterior surfaces of the condyle and distal to the growth plate. The implant site was prepared by drilling under sterile saline irrigation using a series of dental burs. The diameter of the final bur was slightly smaller than that of the implant, and the implants were inserted with an initial interference fit. The implantation site and procedure provided initial contact between cancellous bone and the entire length of the porous-surfaced or plasma-sprayed region of the implants. Each rabbit received one porous-surfaced implant in one condyle and one plasma-sprayed implant in the contralateral condyle. The side (right or left) and order of placement of the implants were randomized. The rabbits were observed closely following surgery and were permitted normal ambulation. Buprenorphine HCl was administered as required to control postoperative discomfort.

Implants were placed in 21 rabbits. Seven rabbits were allotted to each of three groups: 4, 8, or 16 days of healing. In addition, seven pairs of fresh-frozen femurs from rabbits used in unrelated experiments were obtained and allotted to the immediate postoperative group (0 days of healing). This group was used to assess the initial press-fit condition of the two implant designs. Implants were placed in these femurs (after thawing) according to the procedure described above.

After the prescribed healing time, the rabbits were euthanized by T-61 euthanasia solution (Hoechst Canada, Regina, Saskatchewan, Canada) and bone sections (femoral condyles with the implants intact) were harvested.

Histological examination

The bone sections from two of the seven rabbits in each group were stored in 10% formalin and assigned for histological examination. Ground nondemineralized sections were prepared from the implants using methods described previously.\(^{15}\) The 30-μm sections were stained with a 1:1 mixture of 0.3% Toluidine blue and 2% sodium borate, and then counterstained with Unna’s variant of Van Gieson’s stain. The sections were examined by light microscopy and back-scattered electron microscopy to detect mineralization of the tissue within the interface zone.

Mechanical testing and SEM examination

The bone sections from the remaining five rabbits in each group were assigned for mechanical testing and temporarily stored in saline. Pull-out tests were performed to determine characteristic load-deflection curves for the two implant designs at each of the time points. The tests were performed on fresh specimens (within 2 h of harvesting) using a custom-made fixture attached to an Instron test machine under displacement control at a rate of 1 mm/min (Fig. 3). The loading rod was attached to the implants by way of the internal threads. The fixture and specimen preparation ensured that the implant long axis was aligned with the Instron actuator. The precise alignment and tapered shape of the implants ensured that the load-deflection curve was characteristic of the properties of the tissue in the interface zone and the interaction of the tissue with the implant and host bone. The maximum pull-out force and maximum tangential stiffness were determined from the load-deflection curves; these parameters were used to indicate the quality of the attachment of the implants. Wilcoxon one-tailed paired-sample tests were performed at each time point to test the hypothesis that the porous-surfaced implants provided greater attachment.
strength and stiffness than the plasma-sprayed implants. Following pull-out, the extracted implants were temporarily stored in 10% formalin, and then dehydrated, critical-point dried, and coated with a thin platinum conducting layer for examination by scanning electron microscopy.

RESULTS

Day 0

The histologic sections demonstrated that immediately after surgery, the surfaces of both implant designs were in contact with the host bone and bone fragments created during surgery. Scanning electron microscopy was not performed on the day 0 implants, since tissue healing and ingrowth could not have occurred with these specimens.

Because of the tight initial interference fit of the implants, the mechanical properties of the interface zone were dominated by friction between the surface of the implants and the surrounding bone. The pull-out strength and maximum stiffness for the two implant designs were comparable at this time point [Fig. 4(a,b)] \( (p > .5) \).

Day 4

Four days after implantation, the necrotic bone created during surgery had resorbed, and a well-defined interface zone had formed adjacent to both implant designs [Fig. 5(a,b)]. The histological sections indicated that the interface zones for both designs were approximately 150 \( \mu \)m wide and filled with fibrin and loose fibrous extracellular matrix. The scanning electron micrographs indicated that the fibrin and collagen matrix was extensively interdigitated with the three-dimensional interconnected structure of the porous surface regions [Fig. 6(a)]. The interaction of the healing tissue with the plasma-sprayed implants, however, was limited to isolated regions with recesses and undercuts [Fig. 6(b)]. The porous-surfaced implants also appeared qualitatively to have a greater percentage of their surface area covered with matrix.

The more extensive tissue integration and coverage observed for the porous-surfaced implants were reflected by significantly stronger and stiffer attachment with this implant design [Fig. 4(a,b)] \( (p < .05) \). For both implant designs, the force-displacement curve was nonlinear, with a toe region and increasing stiffness with increasing strain.
Day 8

After 8 days of healing, there was increased coverage and interdigitation of the healing tissue with the surface regions of both implants. However, the matrix around the porous-surfaced implants was more dense and extensive than that around the plasma-sprayed implants [Fig. 7(a,b)]. In fact, in some areas of the porous surface regions, the fibers of the collagen matrix appeared to be “bonded” to the surface of the particles, thereby providing excellent tissue–implant attachment [Fig. 7(a)]. In addition, the back-scattered electron micrographs demonstrated early evidence of osteoid formation and mineralization in some areas of the porous-surfaced interface zones [Fig. 8(a)], whereas the same degree of mineralization was not evident in the plasma-sprayed interface zones [Fig. 8(b)].

As a result of the better tissue integration and earlier mineralization, the attachment of the porous-surfaced implants was stiffer and stronger than that of the plasma-sprayed implants [Fig. 4(a,b)] (* p < .05).

Day 16

After 16 days of healing, both implant surfaces were well covered and extensively integrated with mineralized tissue, osteoid, and dense matrix. As well, the scanning electron micrographs showed numerous active osteoblasts on both implant surfaces [Fig. 9(a,b)]. Back-scattered electron microscopy revealed that both implant designs were osseointegrated by day 16, with extensive mineralization of the interface zone tissues [Fig. 10(a,b)].

At this time point, there were no significant differences in the strength and stiffness of attachment of the two implant designs [Fig. 4(a,b)] (p > .5). Thus, the mechanical test data were consistent with the microscopy evidence at this time point.

DISCUSSION

The objective of this study was to determine whether the dynamics of early tissue healing and the stabil-
ity of bone-interfacing implants were significantly influenced by the geometry of the implant surface for two designs currently used clinically in orthopedic and dental implant systems. Based on histological analysis, back-scattered microscopy, scanning electron microscopy, and mechanical testing, we found that the three-dimensional interconnected structure of the sintered Ti6Al4V porous surface was integrated with healing tissue more rapidly and more extensively than was the irregular geometry of the Ti plasma-sprayed coating. In addition, the tissue in the porous-surfaced interface zone mineralized more rapidly than that in the plasma-sprayed interface zone. Consequently, the porous-surfaced implants developed stronger and stiffer early attachment. These data demonstrate that surface geometry strongly influences healing dynamics and, as a result, the early mechanical stability of implants. Implant surface designs that provide better early stability are expected to improve the potential for osseointegration, particularly in situations in which early implant stability is difficult to achieve and maintain.

The more extensive matrix coverage and more rapid bone formation with the porous-surfaced implants suggests that osteogenic cells were able to initiate matrix formation and mineralization more effectively within the interface zone for this implant design. Although the primary difference between the two implant designs was the geometry of the surface region, the chemical composition of the surfaces also was different. Cell culture toxicity studies indicate that aluminum and vanadium ions released from Ti6Al4V implants can inhibit the differentiation and expression of osteoblasts and suppress the deposition of mineralized matrix.19,20 However, we observed more rapid mineralization in the Ti6Al4V porous-surfaced interface zone, suggesting that if surface chemistry was a factor, it was secondary to and superceded by surface geometry.

Previous studies on the role of surface texture on cell activity and matrix formation provide some insights that are relevant to our observations of the influence of surface geometry on healing dynamics. Surface texture of titanium has been shown to affect the proliferation, differentiation, and production of proteins, growth factors, and cytokines by osteoblast-like cells in vitro.21,22 The particles constituting the sintered porous structure in this study were characterized by submicron (0.1-μm) ridges that were the result of thermal etching during sintering.23 These regular topographical features may have modulated cell activity to accelerate bone formation. The plasma-sprayed sur-

Figure 5. Histologic sections demonstrating a well-defined interface zone adjacent to both the porous-surfaced (A) and plasma-sprayed (B) implants after 4 days of healing. The necrotic bone created during surgery had resorbed by this point, and the interface zone was filled with fibrin and loose fibrous extracellular matrix. Stained with Toludine blue and Van Gieson’s. Original magnification: (A) ×30, (B) ×30.
face did not have a regular surface texture and was devoid of submicron features in certain regions. However, it is not known whether these differences in submicron-sized surface texture were sufficient to influence the healing dynamics to the degree observed in this study, particularly when taken in the context of the significant differences in micron-sized surface geometry.

The surface texture on the particles of the porous surface may have been responsible for the collagen

Figure 6. Scanning electron micrographs demonstrating more extensive coverage and interdigitation of the healing tissue matrix with the porous surface (A) than with the plasma-sprayed surface (B) 4 days postimplantation. Some areas of the plasma-sprayed surface were devoid of tissue (C). The arrows near the center of (B) and (C) indicate matrix on the plasma-sprayed surface. Original magnifications: (A) ×100, (B) ×100, (C) ×1000.
fiber attachment that we observed with the day 8 implants. An initial event in the synthesis of matrix adjacent to an implant surface is the formation of an approximately 0.5-μm-thick, collagen-free calcified tissue layer that juxtaposes the implant surface but is not chemically bonded to it. This cementlike layer is subsequently interdigitated with the collagen matrix of the healing interface zone tissue. Since chemical bonding did not occur at the implant surface, the attachment of the collagen fibers to the particles is apparently a striking example of mechanical interlock between the cementlike layer and the submicron-sized thermal etch ridges. The integrity of this mechanical bond is substantial given that the attachment of the collagen fibers was evident even after the implants had been extracted during mechanical testing.

It has been suggested that surface texture may also dictate the mechanism of osseointegration based on the stability of the fibrin scaffold that forms shortly after implantation. A stable scaffold that is firmly attached to the implant surface will permit osteogenic cells to reach the implant surface where they can initiate bone formation (i.e., contact osteogenesis). Stable attachment of fibrin to the implant is assisted by a roughened surface that provides a greater surface area for protein adsorption and physical features with which the fibrin can become entangled. In this study, however, it is likely that both surfaces were sufficiently textured to provide adequate fibrin attachment. The presence of matrix on both implant surfaces after the pull-out tests indicates that the matrix–implant attachment strength exceeded that of the matrix, and therefore the matrix was sufficiently stable to support cell migration to both surfaces.

An alternative hypothesis to explain the accelerated osseointegration of the porous-surfaced implant is that the local mechanical environment around the porous surface may favor bone formation. Maniatisopoulos et al. hypothesized that the differences they observed in tissue remodeling and implant stability of functionally loaded porous-surfaced and threaded implants were due to local mechanical conditions influencing tissue synthesis. Certainly, the role of mechanical stimuli on implant osseointegration has been demonstrated by numerous experimental studies (Pilliar and Szmkler-Moncler et al., for example). Although the implants in this study were not functionally loaded, they were placed in a location that experiences mechanical forces. Based on the work by Pauwels, Carter suggested that the local mechanical environment in the healing peri-implant interface tissue may influence cell differentiation and expression, and consequently tissue synthesis. Specifically, a history of low distortional strain and low hydrostatic stress ap-
plied to the interface tissue promotes bone formation. Since the mechanical environment in the interface tissue is dependent in part on the surface geometry of the implant, the tissue stresses and strains around a porous-surfaced implant may be more favorable for bone formation than those around a plasma-sprayed implant. Although this hypothesis is somewhat speculative, the basic premise, its application to the tissue–implant interface, and the specific role of surface geometry are initially supported by finite element studies.

A unique aspect of this study is the characterization of the mechanical properties of the tissue attachment before the establishment of final osseointegration. Previous researchers have compared the attachment strength of implants with various surfaces, but typically only after osseointegration had occurred. We are unaware of any study that has characterized the mechanical properties of the attachment of a variety of implant designs by early healing tissue. The paucity of data can be attributed in part to the technical difficulties involved in measuring the mechanical properties of the tissue in the narrow interface zone. We were able to overcome these difficulties by using a test fixture that permitted accurate alignment of the implant and by using a tapered implant. The tapered shape of the implant ensured that once the pull-out test was initiated, the implant surface would not contact bone directly. Thus, only the properties of the interface zone tissue and its attachment to the implant and host bone were measured. The efficacy of the mechanical test was demonstrated by the detectable decrease in strength and stiffness between the tight friction fit at day 0 and the attachment by weak, compliant tissue at day 4.

The decrease in mechanical stability observed for both implant types shortly after implantation is an interesting and important observation. The implants were inserted with an interference fit and were very stable at the time of surgery, as evidenced by the mechanical test parameters measured at day 0. However, 4 days after surgery, the stiffness and strength of attachment had decreased. The microscopy analyses revealed that the necrotic bone adjacent to the implant immediately after surgery had resorbed and was replaced by extracellular matrix, resulting in minimal bone–implant contact. Therefore, the mechanical stability during the early healing period was provided only by the healing tissue and its mechanical interaction with the implant surface region. This finding is consistent with the quantitative histomorphometric observations made by Dhert et al. for implants inserted in a cortical bone site. They found that osteo-

Figure 8. Back-scattered electron micrograph of the porous-surfaced (A) and plasma-sprayed (B) interface zones 8 days postimplantation. The arrows near the center of (A) indicate examples of areas with matrix mineralization in the porous-surfaced interface zone. The same degree of mineralization was not evident in the plasma-sprayed interface zone. Original magnifications: (A) ×100, (B) ×100.
clastic resorption occurs following implantation, resulting in reduced bone–implant contact compared with the immediate postoperative situation. With this study, we have demonstrated for the first time the mechanical consequences of this healing response: Implant stability may be reduced in the period following surgery despite a tight initial interference fit.

Another clinically relevant finding is the early mechanical stability that was provided by the porous-surfaced implants. Early loading of dental and orthopedic implants can result in excessive relative micromovement that will prevent bone formation and result in nonrigid fixation by fibrous tissue. Since the amount of micromovement is dependent on the stiffness of the implant attachment, an implant design that provides greater attachment stiffness during the early healing period will experience less micromovement. Furthermore, an implant that osseointegrates more rapidly will be less susceptible to the detrimental effects of micromovement and will require a shorter rehabilitation period. In this study, the porous-surfaced implants had stiffer and stronger attachment before bone formation and osseointegrated more rapidly than the plasma-sprayed implants. This suggests that in a situation with early loading, porous-surfaced implants may be more resistant to the detrimental effects of micromovement, and therefore may have a greater potential for osseointegration than plasma-sprayed implants.

Statistical analysis of our mechanical test results indicated differences in the mechanical parameters (interfacial stiffness and pull-out strength) at days 4 and 8. We did not detect differences in the mechanical parameters at days 0 and 16, possibly owing to the limited power of our statistical tests. However, the mechanical data were supported by the microscopy analyses which demonstrated that the tissue integration and maturity was comparable for the two implant designs at days 0 and 16. Therefore, the porous-surfaced and plasma-sprayed implants were similarly stable at the time of implantation and following osseointegration, which would be expected for nonfunctional implants placed in the site and species used in this study. Although osseointegration of both implant designs occurred within 16 days in the rabbits, the rates of tissue maturation and bone formation would be slower in humans. Thus, in a clinical setting, the critical period during which an implant is susceptible to micromovement effects would be extended, and the differences in healing dynamics between the two implant designs investigated in this study may be exaggerated.

In this study, we focused on the early healing period. Friedman et al. demonstrated that CoCr po-

Figure 9. Scanning electron micrograph taken 16 days after implantation showing extensive coverage and interdigitation of the porous (A) and plasma-sprayed (B) surfaces with mineralized tissue and dense matrix. Note the numerous active osteoblasts lining both implant surfaces. Original magnifications: (A) ×500, (B) ×500.
rous-surfaced implants had greater bone apposition and shear strength than CoCr plasma-sprayed implants 6 and 12 weeks after implantation in the femoral condyles of rabbits. Luckey et al. also found long-term differences in shear strength between CoCr porous-surfaced and plasma-sprayed implants, although their study had insufficient statistical power to demonstrate significance. In light of our finding that the two implant types have comparable stability once initial osseointegration occurs, the results obtained by Luckey et al. and Friedman et al. suggest that the long-term term success of an implant is also dependent on the bone remodeling that occurs after osseointegration.

In conclusion, we have demonstrated that surface geometry can influence the early healing dynamics around bone-interfacing implants with significant consequences in terms of early implant stability. These results suggest that appropriate selection of surface design can improve early implant stability and induce an accelerated healing response, thereby improving the potential for implant osseointegration.

The authors thank Susan Carter, David Abdulla, Chris Pereira, and Robert Chernecky for their expert technical assistance. The implant substrates and sintered porous surfaces were kindly provided by Innova Corporation (Toronto, Ontario, Canada).

References