CHAPTER 14. IMPLANTS

DEFINITIONS

Osseointegration: A direct contact, on the light microscopic level, between living bone tissue and an implant.

Biointegration: A bonding of living bone to the surface of an implant which is independent of any mechanical interlocking mechanism.

Peri-Implantitis: A term used to describe inflammation around a dental implant and/or its abutment.

CLASSIFICATIONS

Lekholm and Zarb (1985) proposed classifications for residual jaw shapes and bone resorption patterns following extraction. A classification was also proposed for associated bone quality. A brief description of these classifications follows:

Jaw Shape-Bone Resorption Pattern: 1) most of the alveolar ridge is present; 2) moderate residual ridge resorption has occurred; 3) advanced residual ridge resorption and only basal bone remains; 4) some resorption of basal bone has started; and 5) extreme resorption of basal bone has taken place.

Bone Quality: 1) homogenous compact bone; 2) thick layer of compact bone surrounds a core of dense trabecular bone; 3) thin cortical bone with dense trabecular bone of favorable strength; and 4) thin layer of cortical bone with low density trabecular bone.

IMPLANT/TISSUE INTERFACE

The implant/soft tissue interface is similar to that present in the natural dentition, with a functional junctional epithelium containing basal lamina and hemidesmosomal attachments. McKinney et al. (1985) suggested that the dense linear body of the basal lamina was composed of glycoproteins produced by fibroblasts and that junctional epithelial cells secrete laminin, resulting in a basal lamina as the epithelium migrates down the implant surface. Although Jansen et al. (1985) reported that this attachment was only associated with hydroxyapatite-coated implants, ultrastructural studies have revealed a similar attachment to titanium (Gould et al., 1981). Following exposure of titanium to air or water, a very stable 3 to 5 Å thick surface oxide layer has been demonstrated. Epithelial cell attachment to this surface oxide layer (Kasemo and Lausmaa, 1985). Brunette (1988) studied the orientation of epithelial cells in grooved titanium surfaces and observed that migration and cell orientation follow the axis of the grooves. The author suggested that horizontal grooving of the non-screw titanium surface (titanium collar-abutment cylinder) may impede apical epithelial migration.

While a lack of an absolute biologic attachment between the implant and surrounding connective tissue has been suggested (Stallard, 1985), in vitro fibroblast attachment to titanium surfaces has been demonstrated by Dmytryk et al. (1990). In addition, circumferential connective tissue fibers have been observed in association with the implant post (James, 1976). Ultrastructural evaluation of the human connective tissue-implant interface revealed bundles of collagen, often directed towards the implant surface, with a 20-nm thick proteoglycan layer between the connective tissue and the titanium oxide surface. No evidence of toxic or foreign body reaction has been seen between the implant-connective tissue interface (Donley and Gillette, 1991). Fiber thickness and orientation are thought to be dependent on the functional load placed on the implant (Stallard, 1985). Fibroblast orientation has been found to differ, depending on the texture of the titanium surface. Inuoe et al. (1987) found no distinct cellular orientation when cells migrated onto porous titanium surfaces. However, Lowenberg et al. (1987) reported a more favorable orientation of cells to porous surfaces when compared to smooth surfaces. Schroeder et al. (1981) noted perpendicular connective tissue fiber attachment into rough plasma-sprayed titanium surfaces. Application of tensile strength removed the sprayed surface from the implant while fiber attachment to the plasma-sprayed titanium surface was maintained.

Osseointegration has been observed between the endosteal-titanium implant interfaces. Sections viewed with electron microscopy have revealed a proteoglycan layer (containing calcified tissue) in direct contact with the titanium oxide surface. The proteoglycan layer is 40 to 200 Å thick (Albrektsson, 1985). In addition, true bonding between titanium and bone has been demonstrated by Steinemann et al. (1986) and Buser et al. (1990). Van der Waal's bonding, hydrogen bonding, and covalent and ionic bonding have been observed between the biomolecular and implant surface (Kasemo and Lausmaa, 1985). The biocompatibility of titanium implants was demonstrated by Buser et al. (1990) when formation of a distinct layer of cementum was observed on the implant surface. In a 12-month study, plasma-sprayed titanium implants were placed in monkeys. Non-submerged hollow cylinder implants were placed in areas of retained root tips. In sites where retained roots directly contacted the implant bed, cementum apposition was noted on titanium surfaces. The collagen fibers of the periodontal ligament were attached perpendicularly to the implant surface and extended into the opposing bone.

Osseointegration also occurs with hydroxyapatite (HA) coated implants (Meffert et al., 1987). The author suggested that only hydroxyapatite, and not titanium, was capable of

true bonding to bone. Bagambisa et al. (1990) reported that an even carpet of multilayered osteoblasts covered the surface of HA implants, with bone infiltrating the porous surface. Hydroxyapatite was not osteoinductive but did act as a nucleation site for osteoid material. Bone formation occurred through epitaxial crystal growth.

CLINICAL CHARACTERISTICS

Marginal tissue response to titanium implant was evaluated by Adell et al. (1986) and Lekholm et al. (1986A). Lekholm et al. reported a relation between plaque and gingivitis and between gingivitis and probing depths, while Adell and colleagues did not. The Lekholm study was cross-sectional and the Adell study was longitudinal. Lekholm et al. measured gingivitis (80%) by bleeding on probing while Adell et al. measured gingivitis (15 to 20%) based on visual signs of inflammation. In the Adell study, plaque was present in only 25 to 30% of the implant sites while 54% in the Lekholm study had plaque. Lastly, the Adell study population was composed of edentulous patients whereas 8 of 20 of Lekholm patients were partially edentulous. Both groups reported increased recession, with the same mean bridge to gingiva distance (3.2 mm). Attached gingiva was present in 65% (Adell) and 51% (Lekholm) of all buccal and lingual surfaces. Probing depths were generally low, with none > 5 mm in the Adell group and 15% > 6 mm in the Lekholm study. Adell et al. reported 0.9 mm bone loss the first year and 0.05 mm annually for the next 2 years (based on radiographic findings). Both groups reported minimal histological inflammation, with no inflammation in 49% of the biopsies and slight inflammation in 33% (combined results). Currently, mobility and radiographic bone loss represent the most reliable methods of detecting implant failure (Newman and Flemmig, 1988).

MICROBIOLOGY

The implant microflora are derived from the natural flora of the oral cavity (Heimdahl et al., 1983). Bacterial adherence to enamel and titanium seem to differ, with titanium exhibiting a 5-fold decrease in adherence of *Actinomyces viscosus* and a slight decrease in adherence of *Streptococcus sanguis* (Wolinsky et al., 1989). Rams et al. (1984) noted that bacteria from healthy edentulous implant sites were composed primarily of non-motile coccoid cells (64.2%), filamentous rods, and minimal numbers of spirochetes (2.3%). "Corncob" formations were also commonly seen. In a study evaluating colonization of newly exposed titanium implants, Mombelli et al. (1988) reported no significant changes in the proportions of microorganisms over a 6-month period. Eighty percent (80%) of the cultivated bacteria were Gram-positive facultative cocci. The authors concluded that in health, the subgingival implant microbiota were similar to that of the natural healthy dentition. Apse et al. (1989) compared the implant microflora in edentulous and partially edentulous patients, noting greater numbers of motile forms and less black-pigmented *Bacteroides* and wet spreaders in the edentulous group. In the partially edentulous group, there was no significant predilection for any type of bacteria at either the implant or tooth sites. The authors suggested that the differences between edentulous and partially edentulous implant sites may be the result of contamination of the peri-implant sites by pathogens from periodontal pockets. These findings are in agreement with Lekholm et al. (1986B) who also reported a similar microbial composition adjacent to natural teeth and titanium fixtures. Non-motile rods, filaments, and fusiforms comprised 50% of the microflora in partially edentulous healthy implant and tooth sites. The remainder was comprised of cocci (25%) and motile rods (25%). Few spirochetes, and no *Actinobacillus actinomycetemcomitans, Bacteroides gingivalis*, or *Prevotella intermedia* were noted around implant sites.

As inflammation and probing depths (> 5 mm) increase, elevated levels of spirochetes and decreases in coccoid cells are noted (Rams et al., 1984). An increase in the number of Gram-negative anaerobic flora is observed, with equal proportions of *Bacteroides, Fusobacterium*, and vibrios (Newman and Flemmig, 1988).

Failing implants have been associated with a florium which differs from that seen in health. Rams et al. (1983) evaluated the microbiota around 3 failing ceramic implants in edentulous patients. An increase in spirochetes (31 to 56%) and motile rods (15 to 31%) with a decrease in coccoid cells (19 to 31%) was reported. "Brush forms," composed of spirochetes and non-motile rods, were also noted. Small and intermediate size spirochetes were observed with electron microscopy. Mombelli et al. (1988) reported similar findings, noting a decrease in cocci and an increase in spirochetes, *Fusobacterium*, and *Actinomyces*. The microflora associated with failing implants are very similar to that of periodontal disease. The composition of implant-associated plaque was consolidated and presented in chart form by Newman and Flemmig (1988) (See Table 1).

LONG-TERM STUDIES

When interpreting long-term implant results, the reader should consider the criteria for success, type of implant system used, site of implant placement (maxillary or mandibular), and edentulous status (partially or fully edentulous). The criteria for success may differ between studies, with many of the earlier studies not including implants that failed, but the prostheses were retained or implants left sleeping as failures. More recent studies have determined success based on a lack of mobility and lack of peri-implant radiographic radiolucency. Albrektsson (1986) proposed the following criteria for evaluation of implant success: 1) no clinical mobility; 2) no radiographic peri-implant radiolucencies; 3) < 0.2 mm annual bone loss following the implant's first year of service; and

TABLE 1. SUBGINGIVAL PLAQUE COMPOSITION IN OSSEOINTEGRATED TITANIUM FIXTURES

Stable Implants
Streptococcus sanguis (6.9%)
Streptococcus mitis
Streptococcus acidominimus
Peptostreptococcus
Peptococcus
Actinomyces viscosus (4%)
Actinomyces naeslundi
Veillonella parvula
Fusobacterium nucleatum (6.5%)
Non-pigmented *Bacteroides*
Black-pigmented *Bacteroides*
Prevotella intermedia (0.9%)
Campylobacter
Vibrios
Motile rods
Spirochetes
Curved rods
Failing Implants
Black-pigmented *Bacteroides*
Prevotella intermedia (5.7%)
Capnocytophaga
Fusobacterium ssp (15.3%)
Spirochetes
Motile rods
Surface translocating bacteria
Curved rods
Staphylococcus aureus
Pseudomonas aeruginosa
Klebsiella pneumonia
Enterobacter cloacae

Taken from Newman and Flemmig, *J Dent Ed* 1988;52:737. Reproduced with permission.

4) lack of pain, infection, paresthesia, or violation of the mandibular canal.

The Branemark implant system has been extensively evaluated with multiple long-term studies from various investigators and centers. Adell and co-workers (1981) reported 5 to 9 year single-center success rates of 91% for the mandible and 81% for the maxilla. Albrektsson et al. (1988) performed a multi-center study which included placement of 8,139 consecutively placed implants in edentulous patients. They noted a 5 to 8 year success rate of 99.1% in the mandible and 84.9% in the maxilla. Seventy-eight percent (78%) of the mandibular failures occurred during the first year and 13% during the second year. More recently, Ahlquist et al. (1990) evaluated 269 implants over a 2-year period. The authors reported success rates of 97% in the mandible and 89% in the maxilla. Average bone loss during the first year was 1 mm for the mandible and 1.6 mm in the maxilla. During the second year, the mandibular sites lost an average of 0.04 mm and maxillary sites 0.1 mm. Implant placement in partially edentulous patients was evaluated by van Steenberghe et al. (1990). This 9-center study, which included 558 consecutively placed implants, showed a 1-year success rate of 96%. Reasons for loss or unaccounted for implants included failure to integrate (3.4%), patient withdrawal (2%), prosthodontic reasons (1.1%), and failure during prosthodontic treatment (0.2%). In summary, Branemark implants in both edentulous and partially edentulous patients have a success rate greater than 90%.

The Integral (Calcitek) hydroxyapatite-coated titanium system was evaluated by Kent et al. in 1990. This 5-year longitudinal follow-up study assessed 772 hydroxyapatite implants (Integral and IMZ) in 229 patients. The criteria for success were based on whether or not the implants were removed or left sleeping. Reasons for implant removal included lack of integration at stage 2, > 50% bone loss at stage 2, lack of bone support, loss of bone during function, malposition, and psychiatric reasons. Of the 745 implants placed, 28 were removed and 1 was left as a sleeper, for a success rate of 94.6%. This compares well with Golec (1990) who noted a 93.7% success in the 2,249 implants studied over a 5-year period.

The IntraMobile Cylinder (IMZ) implant system was originally introduced in 1978. In 1984, a plasma-sprayed hydroxyapatite (HA)-coated surface was introduced. Kirsch and Ackerman (1989) published the results of a 10-year study and reported an overall success rate of 97.8%. Implant failure was defined as failure to integrate during primary healing, implant mobility after functional restoration, or soft tissue sequelae. Examples included bone loss, pain, and change in clinical parameters around the implant (i.e., GI, bleeding, exudate). While the 10-year data included evaluation of both types of implants (i.e., titanium plasma-sprayed and HA-coated), only the 4-year data for the modified (HA-coated) IMZ implants are included. A total of 804 of these implants were placed in 333 patients, with 72.9% placed in partially edentulous areas. Two of the 804 implants failed, for a success rate of 99.8%. These findings are in agreement with Babbush et al. (1990) who reported a 97 to 98% 10-year success rate in the 3,436 implants placed. These results are in contrast to Kent et al. (1990) who noted a 63%, 5-year success rate for 27 HA-coated IMZ implants.

The Core-Vent implant system has been evaluated by several researchers with contradictory results. Malmquist and Sennerby (1989) noted success rates ranging from 58 to 77%. Albrektsson and Lekholm (1989) reviewed multiple implant systems. In addition to those mentioned above, the authors also reviewed the ITI and sapphire implant systems. Success rates of 85 to 92% over a 1- to 92-month time frame was reported for the ITI implant system (Schroeder et al., 1988), while the success rate was 77.7% for sapphire implants (Koth et al., 1988).

DIAGNOSIS AND PROGNOSIS

When evaluating patients for implant placement, a multidisciplinary approach is necessary to ensure maximal benefit from the therapy provided. A thorough medical history

should be taken to rule out immediate anesthetic and surgical risks, psychologic and psychiatric risks, medical threats to long-term retention, and long-term deleterious effects of implants on health (Matukas, 1988). Adell et al. (1981) proposed absolute contraindications for implant placement which included pregnancy, hemophilia, granulocytopenia, steroid use, prophylactic antibiotics, brittle diabetes mellitus, Ehlers-Danlos syndrome, osteoradionecrosis, radiation, renal failure, organ transplantation, anticoagulation therapy, hypersensitivity, fibrous dysplasia, and regional enteritis.

In addition to a thorough medical history, a comprehensive dental examination should be performed. Radiographic examination should include a panoramic, periapical, or occlusal film, cephalographs, tomograms, or computed tomography scan. In dentate patients, a periodontal examination should be performed and periodontal disease controlled prior to implant placement. Variables which can affect implant success should be assessed. These include bone type, dental arch (maxilla versus mandible), implant location (anterior versus posterior), anatomical variations, presence of natural dentition, implant type, and operator expertise. Taken together, these variables may aid in determining prognosis. Jaffin and Berman (1991) noted that the quality of bone was the single greatest determinant in predicting fixture failure. Type IV bone had fixture loss rates of 44% for the maxilla, 37% for the posterior mandible, and 10% for the anterior mandible. This was in contrast to type I, II, and III bone with fixture loss rates of 3.6% for the maxilla, 6.8% for the posterior mandible and 1.2% for the anterior mandible. van Steenberghe et al. (1990) also associated implant failures with quality of bone, with 22% of patients with type IV bone patients having one or more implant failures. The authors reported gender (failure: males, 13%; females, 7%) and small fixture size (failures: 7 mm, 10.7%; 10 to 13 mm, 5.9%; 15 mm, 0%) as factors associated with implant failures. Ahlqvist et al. (1990) noted increased bone resorption in anteriorly placed implants (versus posterior) and in patients with minor preoperative alveolar bone resorption. Another factor which may affect implant success is whether or not the patient is edentulous. Because implants placed in dentate patients harbor the same bacteria as the natural teeth, the likelihood of periimplant breakdown may be increased.

Implant placement in irradiated patients has not been without controversy. Matukas (1988) stated that implant placement in a site with a history of radiation > 4,000 rads is contraindicated and Adell et al. (1981) listed radiation as an absolute contraindication. However, Albrektsson et al. (1988) reported 100% success rate in the mandible (56 implants) and 88% in the maxilla (16 implants) when Branemark implants were used. These rates compare well with non-irradiated patients, supporting the use of implants in selected radiation cases.

SURGICAL TECHNIQUES

Soft Tissue Management

The soft tissue management during placement and uncovering of the implant should include a review of proper access and the anatomy of the implant site. In a review of implant surgical techniques, Moy et al. (1989) discussed the three most common flap designs for stage one surgery: These include the labial split-thickness flap, mid-ridge flap and lingual-palatal off-ridge flap. In addition, a split-thickness palatal flap (Krauser, 1989) or an overlapped flap (Langer and Langer, 1990) may be used.

The labial split-thickness flap was described by Moy et al. (1989) as providing the "best access for visibility, ease of placement of implants, and accommodation for surgical stents." This procedure is generally used in the mandibular anterior region. A superficial semilunar incision is made laterally on the mucosa from canine to canine at two-thirds the sulcular (vestibular) depth. The fibers of the mentalis and the underlying periosteum are then incised with the blade placed perpendicular to the labial plate. Blunt dissection is performed subperiosteally, proceeding posteriorly until the mental foramen is palpated. Once the mental nerve is visualized and retracted, the dissection continues in a coronal direction until the lingual aspect of the ridge is visualized. Care must be taken to avoid excessive facial dissection, as it may lead to coronal movement of the flap, thus decreasing vestibular depth. Following implant placement, closure of the flaps is achieved in layers to ensure complete closure and to reduce the possibility of hematoma formation. This flap design works well everywhere except in the maxillary anterior region, where esthetics is of concern. The main disadvantage of this procedure includes occasional opening of the incision with subsequent delayed healing in the vestibular area (Krauser, 1989).

In the mandible, the mid-ridge flap is used when there is concern about injury to the mental nerve. Reflection of the flap is limited, thereby preventing visualization of the complete anatomy of the ridge. Because of limited access, osteoplasty is difficult to perform. In addition, cases with knife-edge ridges have increased incidence of dehiscences with this flap approach (Moy et al., 1989).

The lingual/palatal off-ridge flap is often used in the maxillary anterior region. This design permits adequate access for visualization and for use of a surgical stent, because the blood supply is limited on the palatal and healing often occurs by secondary intention. In addition access for closure is more difficult with this flap design (Moy et al., 1989).

In the split-thickness palatal flap technique (Krauser, 1989), a full-thickness flap is reflected from the palate to the facial, which continues as a split-thickness dissection on the buccal. According to the author, this provides a biologic seal over the labial periosteum which can be especially useful in cases where possible facial perforation of the implant is anticipated. With the palatal approach, the

blood supply to the facial pedicle flap is limited, and flap necrosis with hematoma formation often develops.

Another surgical flap modification for stage 1 surgery is the overlapped flap design described by Langer and Langer (1990). A partial thickness flap is reflected either from the buccal or palatal aspect of the ridge. In the mandible, the buccal approach is the technique of choice. In the maxilla, the palatal approach is used. With the palatal approach, the split-thickness flap becomes thicker as it goes apically until bone is reached, in an effort to preserve the flap blood supply. Two beveled vertical incisions are then made on the inner flap, to facilitate flap reflection. Vertical incisions are placed on the outer flap as needed. The full-thickness double flaps are then reflected, providing visualization of the ridge. Following implant placement, the flaps are adapted and sutured in place with vertical or horizontal mattress sutures. In order to prevent contamination of the fixtures, the sutures should not completely penetrate the underlying flap. Superficial tissue necrosis may occur if sutures are placed too tightly or if inadequate pressure is placed and a hematoma develops under the flaps.

Stage 2 surgery requires much less access and can be accomplished one of two ways. A punch may be used to remove the tissue over the cover screw or a linear incision made. The punch technique does not allow for soft or hard tissue recontouring. In addition, the minimal keratinized tissue present at some sites may be compromised with this procedure. An alternative technique is the use of a full-thickness linear incision over the cover screw. This provides access for thinning the soft tissues or recontouring the bone, while preserving keratinized tissue. No sutures are required for the punch technique. A continuous sling with interproximal mattress suture works well with the linear incision technique (Moy et al., 1989). In addition, keratinized tissue may be restored and esthetics enhanced with periodontal plastic surgical techniques (Israelson and Plemons, 1993).

Implant Placement

During implant placement undue trauma to the osseous structures should be avoided. The critical temperature above which bone will necrose is 47°C. Handpiece speed should be controlled and irrigation provided to prevent irreversible damage to bone. Tapping of screw type implants is performed at low speeds (15 rpm) to remove enough bone (0.125 mm) for a tight fixture fit. With screw-type implants, bicortical stabilization of the implant is desired. Overall success is dependent on the quality of the bone at the implant site. Screw-type implants are often placed in less than ideal angulations to achieve bicortical stabilization. With HA-coated cylinders and screws, lamellar-type bone formation can be expected even in spongy bone (Krauser, 1989). The length of the implant has been previously considered more important to the success of the implant than the diameter (van Steenberghe et al., 1990; Krauser, 1989). However, "wide" fixtures are now available which facilitate biocortical stabilization and provide equvalent or increased surface area.

Regenerative Procedures

Favorable results have been reported with regenerative procedures adjacent to implants. Dahlin et al. (1989) evaluated the use of expanded polytetrafluoroethylene (ePTFE) membrane over exposed (3 to 4 threads) newly placed implants in the rabbit tibia. By the sixth week, all of the exposed surfaces on the test sites were filled (3.8 mm) with new bone of uniform thickness. The control sites (no membrane) averaged only half as much bone fill (2.2 mm), with the bone becoming thinner coronally. Becker and Becker (1990) presented 4 implant cases where ePTFE implant augmentation material was used to enhance bone formation in extraction sites and over dehiscences of newly placed titanium implants. The augmentation material was left in place until the second stage surgery (6 to 8 months). Regeneration was noted in 3 out of 4 cases (fourth case still pending), with complete defect fill (3 mm) in both dehiscence defect sites and fill of 6 of the 8 threads in the extraction site. Histologic evaluation of the ePTFE material revealed bone woven into the membrane.

Mucosal Grafts

Soft tissue complications arising around implants include soft tissue proliferation, retractable margins, inadequate vestibular depth for hygiene, and peri-implant mucositis. While conservative treatment should be performed to eliminate these conditions, gingival grafting may be indicated if these measures are not successful. Where recession involves only one area, the vestibule is of normal depth and there is adequate donor tissue adjacent to the recipient site, a contiguous gingival graft may be considered (Horning and Mullen, 1990). Free gingival grafts are indicated when there is inadequate donor tissue adjacent to the recipient site or when the vestibular depth is minimal or inadequate. With the free gingival grafts, the mucosa should be periodically cut back during the healing phase to prevent coronal migration over the denuded connective tissue at the grafted site.

MAINTENANCE

While the reported long-term success rate for implants is good, it is important to monitor the patients and periodically evaluate and debride the implant. Maintenance intervals may vary depending on the patient's ability to maintain the area. However, 6 months is the maximum, with 3 months being the average. Orton et al. (1989) described the dental professional's role in implant monitoring and maintenance. While it is important to document clinical parameters such as probing depth, clinical attachment level, bleeding on probing, and plaque and gingival indices, their prognostic value is currently unknown. Progressive changes

in probing depths are more important than absolute depths. Mobility is a sign of implant failure. Periodic radiographs should be taken to evaluate for loss of implant integration (radiolucency) or excessive horizontal bone loss. With Branemark fixtures, the mean horizontal bone loss during the first year is approximately 1 mm and 0.1 mm/year thereafter (Albrektsson and Lekholm, 1989). Radiographs should be taken after the second-stage surgery at yearly intervals for the first 3 years to ensure proper fit of the abutment. When removing accretions from the implant, care must be taken not to damage the surface. Scratches on the titanium surface may result in increased plaque accumulation, corrosion, and a decrease in cell spreading (Fox et al., 1990). Rapley et al. (1990) evaluated various instruments and materials to determine the surface changes produced in titanium abutments. The following were evaluated: rubber cup, rubber cup with flour of pumice, air abrasive, interdental tapered brush, Eva yellow plastic tip, soft nylon toothbrush, universal plastic scaler, ultrasonic scaler, and a stainless steel scaler. Following instrumentation, the abutments were viewed with electron microscopy. Instrumentation with the interdental brush, Eva plastic tip, rubber cup, air abrasive, soft nylon toothbrush, or plastic scaler did not alter the implant surface. The rubber cup with the flour of pumice resulted in a smoother surface than the control. The air abrasive system produced a surface with dark discolorations, possibly indicative of surface corrosion. Metal scalers appeared to gouge the titanium surface and produced significant vertical grooving. The air abrasive caused severe roughening, which was readily evident at the macroscopic level. These findings are in agreement with Fox et al. (1990) who used a helium neon laser to evaluate implant roughness. Surfaces received 30 vertical strokes in a 2 mm area. Greater roughness was noted in surfaces treated with metal scalers (titanium curet > stainless steel) than those treated with plastic scalers or untreated controls (plastic scalers similar to control). A subsequent study by the same group (Dmytryk et al., 1990) reported cell attachment to be impaired in titanium surfaces scaled with metal instruments. The following hierarchy of fibroblast attachment was found: plastic curet > untreated control > titanium scaler > stainless steel scaler. This study suggests that other factors in addition to surface roughness may affect cell attachment since the titanium scaler which produced greater surface roughness than the stainless steel scaler did not affect cell attachment as much as the stainless steel scaler. In theory, metal scalers other than titanium cause corrosion, obliterating the titanium oxide surface layer and impairing cell attachment. These results suggest that metal scalers and instruments such as ultrasonic scalers or the air abrasive should not be used on titanium surfaces since damage to the titanium-oxide surface will occur. However, plastic scalers and rubber cup polishing with flour of pumice will maintain or enhance the titanium implant surface.

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