Immediate Loading of Modular Transitional Implants: A Histologic and Histomorphometric Study in Dogs

Yuval Zubery, DMD/Nitzan Bichacho, DMD**/
Ofer Moses, DMD***/Haim Tal, DMD, MDent, PhD*****

Modular Transitional Implants (MTI) are made from pure titanium and are used to support fixed provisional restorations during the osseointegration of definitive implants. This study histologically examined the jaw response to loaded MTIs in the dog mandible. Three implants were inserted transmucosally into each side of the mandible in 3 dogs. Stability was examined using a Periotest. Anterior and posterior implants were splinted using a cemented acrylic resin fixed partial denture to allow immediate loading. The middle implant remained unloaded and was used as a control. Dogs were sacrificed 11 to 12 weeks after implantation, and tissue blocks containing the implants were removed. Histologic examination showed that 10 of the 18 implants had good bone-to-implant contact, with the percentage of bone contacting the threaded portion of the implant varying from 30% to 65%. There was no statistical difference (P > 0.1) in percentage of bone-to-metal contact between loaded and unloaded implants. Six implants were entirely surrounded by connective tissue with or without inflammation; two implants were lost during the study. The success rate did not differ between loaded and unloaded implants. In the successful implants trabecular bone made good contact with the implant, forming supporting struts. There was bone remodeling in some bone-to-metal contact areas. It is believed that success was mainly influenced by the initial bone density at the implant site and by the uncontrolled load that the animals applied to the implants during the early healing stage. (Int J Periodontics Restorative Dent 1999;19:343–353.)

*Private Practice, Ramat Hasharon, Israel.
**Department of Prosthetic Dentistry, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Israel.
***Instructor, Department of Periodontology, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Israel.
****Professor and Chairman, Department of Periodontology, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Israel.

Reprint requests: Prof Haim Tal, Head, Department of Periodontology, School of Dental Medicine, Tel Aviv University, Tel Aviv 69978, Israel.
e-mail: talhaim@post.tau.ac.il

Osseointegration of dental implants requires a period of 3 to 6 months, depending on bone quality. During this period trauma to the implant or to the covering soft tissue may interfere with the osseointegration process and with the coronal peripheral bone and connective tissue healing.[1,2] In addition, prevention of infection and epithelial downgrowth has been attributed to implant submergence.[3]

While the plea from the surgeon is to avoid any load on top of the soft tissue covering freshly placed implants, the goal of the restorative dentist is to allow the patient to continue normal, and even enhanced, oral functions with no delay. It has recently been claimed that Modular Transitional Implants (MTI, Dentatus) and Modular Prosthetic Systems (MTI-MP, Dentatus) may permit the placement of fixed provisional restorations at chairside, during or immediately after insertion of the definitive implants.

This study was undertaken to histologically examine tissue

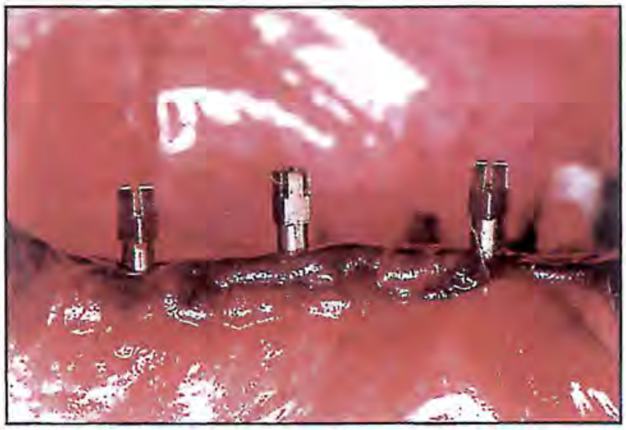

Fig 1a Three MTIs placed in an edentulous site in a dog mandible, with threaded part of implant 1 mm below mucosal crest.

Fig 1b Acrylic resin provisional restoration retains mesial and distal MTIs as abutments; middle implant remains unloaded beneath.

response to immediate loading of MTIs inserted transmucosally in the dog mandible. The study protocol was reviewed and approved by the Tel Aviv University Review Committee for animal care and use.

Method and materials

The first, second, and third premolars were extracted in each side of the mandibles in 3 healthy young adult mongrel dogs. Care was taken not to damage the alveolar ridge during extractions. After 3 months careful manual palpation and bone sounding were performed using a narrow periodontal probe. Presterilized, machine-made, pure titanium MTIs (1.8 mm in diameter and 21 mm in length) were then placed with a manual driver, self tapping into final position with the most coronal threads 1 mm under the mucosal crest. The mucosa was rubbed with 0.2% chlorhexidine gluconate (Corsodyl), and according to the manufacturer's instructions a specially designed, flame-shaped, spiral, steel profile bur (1.4 mm in diameter) was used to penetrate the mucosa and the cortical bone under meticulous saline irrigation. Three implants were then placed in each edentulous site, 5 to 6 mm from one another (Fig 1a). The stability of each implant was determined using a Periotest (Siemens) and the measurements were recorded. An acrylic resin provisional restoration was fabricated chairside and placed using the mesial and distal MTIs as abutments; the middle implant was left unloaded (Fig 1b). Light occlusal contact was established with the opposing teeth. The dogs were maintained on a soft diet for 10 days and then on a regular diet. Implants were brushed twice a week with 0.2% chlorhexidine solution until the end of the study.

Dogs were sacrificed 11 to 12 weeks after implant placement. The jaws were perfused by 10% buffered formalin for 20 min and then dissected. Bone segments containing the implants were placed in 10% buffered formalin.

Histologic preparation and histomorphometric procedure

Specimens were dehydrated and infiltrated with a light-curing embedding resin, then cut to a thickness of 150 µm and polished to a thickness of 35 µm using the techniques described by Donath and Breuner[4] and Rohrer and Schubert.[5] Preparations were stained with Stevenel's blue and Van Gieson's picric fuchsin. For the specimens to be projected and magnified, macrophotographs were taken. The implants were magnified to 70× and the perimeter of the threaded portion of the implant was measured from the top of each crest and apically using a programmable digital curvimeter (Line 5 Electronic Chartmeter, K & R Instruments). The total length of bone in contact with the implant was also measured. Fibrous connective tissue apical to the crests, as well as soft tissue within the bone (marrow), was not included in this measurement. The percentage of the perimeter of the threaded portion of the implant in contact with bone was calculated. The difference between experimental and control specimens was tested using the paired Student's *t* test.

Table 1 **Bone contact with threaded portion of implants**

Dog	Implant No.	Exp/cont	Periotest recording	Bone-to-implant contact (%)
I	1	Exp	6	0
	2	Cont	–2	44
	3	Exp	8	0
	4	Exp	0	33
	5	Cont	1	Failed
	6	Exp	1	51
II	7	Exp	–1	30
	8	Cont	–3	53
	9	Exp	2	54
	10	Exp	–4	57
	11	Cont	–2	65
	12	Exp	0	51
III	13	Exp	1	47
	14	Cont	2	0
	15	Exp	6	Failed
	16	Exp	4	0
	17	Cont	12	0
	18	Exp	8	0

Exp = experimental (loaded); Cont = control (unloaded).

Results

Immediately after implant insertion and before loading, Periotest recordings showed significant variations between implants (–4 to 12) (Table 1). During the clinical part of the study most acrylic resin splints were damaged and repaired repeatedly. Two implants were exfoliated/lost during the study. Even though all implants were clinically stable as judged by clinical percussion at the time of insertion, the implants that exfoliated or did not present osseointegration were previously recorded as 1 to 12; the osseointegrated implants were recorded as –4 to 2.

The success/failure ratio did not differ between loaded and unloaded implants. Seven of the twelve loaded (experimental) implants were osseointegrated (58.3%) and five failed; three of the six unloaded (control) implants were osseointegrated (50%) and three failed.

Implants were divided into 2 groups: osseointegrated and nonosseointegrated. In most of the osseointegrated implants trabecular bone made good contact with the implants, forming supporting struts. Most osseointegrated zones presented good contact with very solid mature bone (Fig 2). In some parts, thicker cortical-type bone was in good contact with some portions of the implant (Fig 3a). Polarized views showed bone remodeling in these areas (Fig 3b). Remodeling of trabecular struts was a less common observation, but it was evident in 3 specimens (Fig 3c). Remodeled and mature bone around the implant apex was observed in 5 specimens (Fig 4).

Clear endosseous bone growth originating on the internal body surface of the mandible was observed in 6 specimens (Fig 5). This may suggest that the trabeculae were growing out to

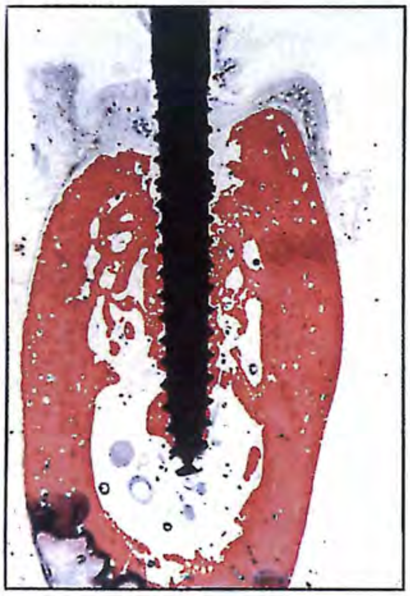

Fig 2a Cross-section of mandible shows osseointegrated MTI in good contact with trabecular bone. Bone is solid and mature. Bone-to-implant contact is 53%. (Original magnification × 2; Stevenel's blue stain.)

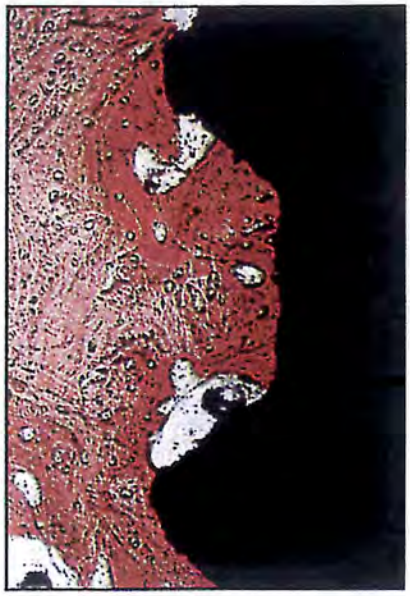

Fig 2b Higher magnification of Fig 2a shows solid contact of mature bone. (Original magnification × 20; Stevenel's blue stain.)

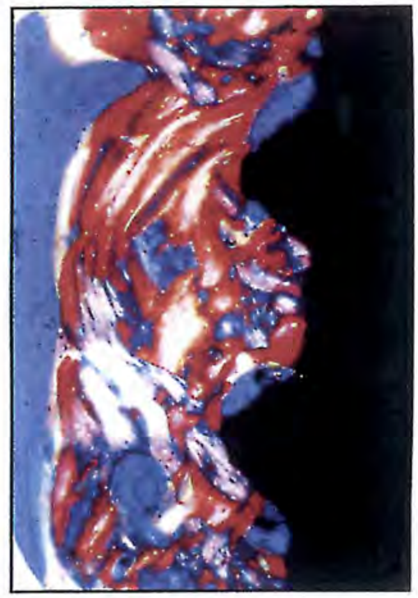

Fig 2c Polarized view of area shown in Fig 2b shows very solid mature bone. (Original magnification × 16; Van Gieson's picric fuchsin stain.)

Fig 3a Cross-section of mandible shows MTI with cortical-type bone in good contact (44%) with some portions of the implant. (Original magnification × 2; Stevenel's blue stain.)

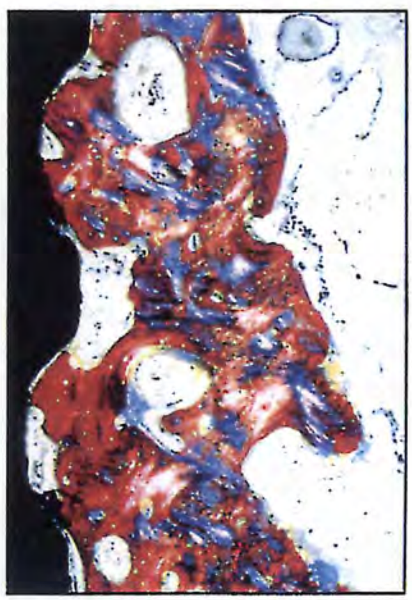

Fig 3b Polarized view from Fig 3a shows bone remodeling at bone area in contact with implant. (Original magnification × 16; Van Gieson's picric fuchsin stain.)

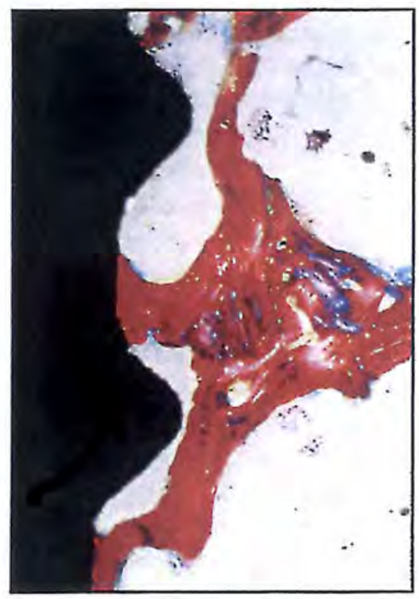

Fig 3c Polarized view from Fig 3a shows trabecular struts in contact with implant and evidence of trabecular bone remodeling. (Original magnification × 16; Van Gieson's picric fuchsin stain.)

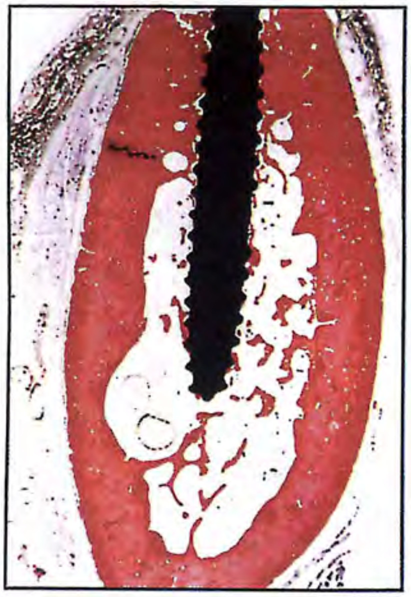

Fig 4a Cross-section of mandible shows good contact between mature cortical bone and coronal part of implant, with many areas (51%) of solid contact. (Original magnification × 2; Stevenel's blue stain.)

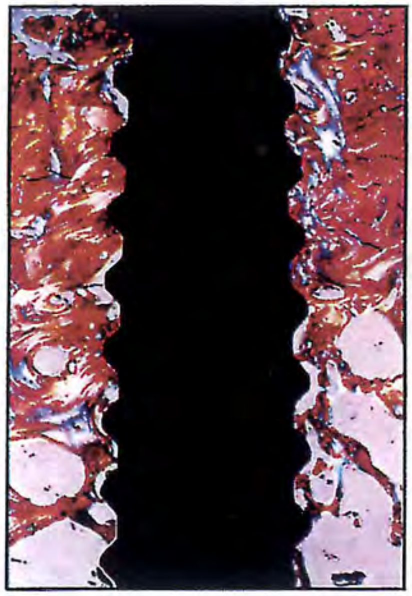

Fig 4b Polarized view shows good bone-to-implant contact with mature cortical bone at neck; more apical trabecular mature and remodeling struts. (Original magnification × 8; Van Gieson's picric fuchsin stain.)

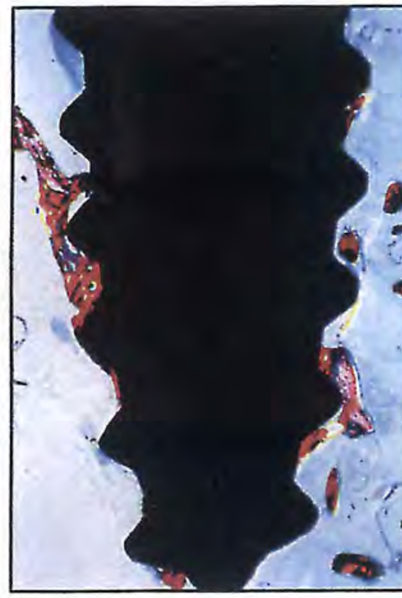

Fig 4c Higher magnification from Fig 4a shows remodeled and mature bone around part of implant. Apex is within inferior alveolar canal, with inferior alveolar nerve and artery < 1 mm from implant. (Original magnification × 10; Van Gieson's picric fuchsin stain.)

Fig 5a (left) Endosseous bone growth originating on internal surface of body of mandible contacts implant. (Original magnification × 10; Stevenel's blue stain.)

Fig 5b (right) Polarized view of Fig 5a shows very good bone-to-implant contact, with relatively young bone at contact phase. (Original magnification × 10; Van Gieson's picric fuchsin stain.)

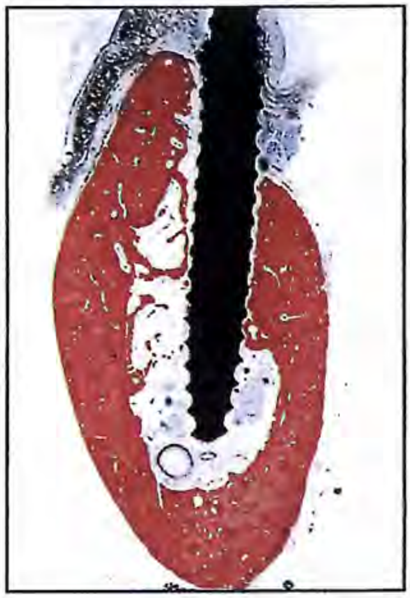

Fig 6 (left) *Cross-section of a mandible with failing loaded implant, which is entirely surrounded by connective tissue. Connective tissue in the coronal half is thicker than that in the apical half. (Original magnification × 2; Stevenel's blue stain.)*

Fig 7 (right) *Mandible with unloaded failing implant, which is entirely surrounded by connective tissue with narrow and generally constant width and no inflammation. (Original magnification × 2; Stevenel's blue stain.)*

support the implant; however, this could not be determined at this level of study.

The percentage of bone contact with the threaded portion of the osseointegrated implants varied from 30% to 65%, with a mean of 48.5% (Table 1). Three unloaded implants presented a mean bone-to-implant contact of 54%; seven loaded implants presented a mean bone-to-implant contact of 46.1% ($P > 0.1$).

In a few specimens it was clear that some of the threaded portion of the implant was above the ridge crest, so it was not expected to be in contact with bone (Fig 2a). Elimination of this factor increased the mean bone-to-implant contact by an additional 7%, to 55.5%; however, no further calculations were carried out along this line.

Histologic observation of the nonosseointegrated implants showed that they were entirely surrounded by connective tissue; the width of the tissue varied between 1 and 2 mm. In loaded nonosseointegrated implants the surrounding connective tissue in the coronal half was generally thicker than that in the apical half (Fig 6). In unloaded nonosseointegrated implants, the thickness of the surrounding connective tissue was generally constant (Fig 7).

In 4 of 6 specimens new trabecular bone (immature "woven" bone) appeared to be growing toward the implant. In nonosseointegrated control implants this type of bone could also be observed in close contact with the implant surface, but with no bone-to-implant contact (Fig 7).

In three of the six nonosseointegrated implants no inflammation was seen within the connective tissue (Figs 6 and 7). Three failing implants located on the left side of the same mandible (# 16, 17, and 18; Table 1) differed from the other failing ones in that chronic inflammatory cells were present in the connective tissue contacting the coronal half of the implant (Fig 8). The peripheral bone of the "socket" area in the two loaded, failing implants (# 16 and 18) was very active. New bone growth was observed, with Sharpey's-like fibers leaving the newly formed bone and going into the connective tissue, but no bone-to-implant contact was present (Fig 9).

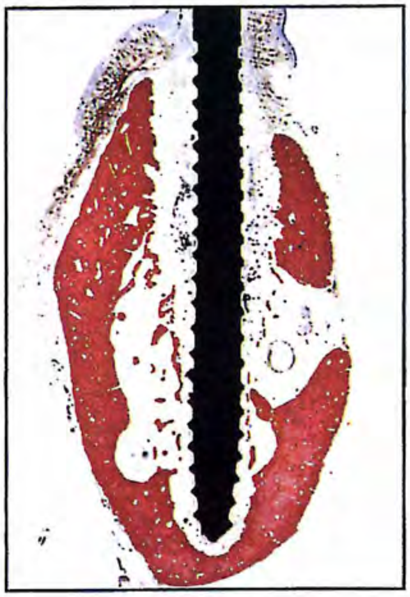

Fig 8a (left) *Failing loaded implant. Funnel-shaped opening through area of alveolar crest has the appearance of what would be seen if the implant was loose and moved buccolingually. (Original magnification × 2; Stevenel's blue stain.)*

Fig 8b (right) *Higher magnification of Fig 8a shows chronic inflammatory cells in connective tissue contacting coronal half of implant. (Original magnification × 8; Stevenel's blue stain.)*

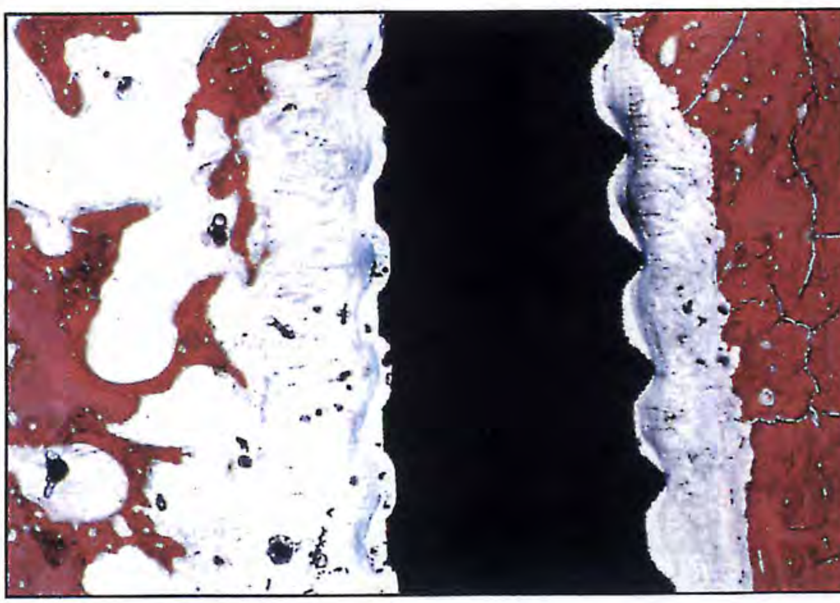

Fig 9 *Failing loaded implant surrounded by very active bone at periphery of socket. New bone growth can be observed with Sharpey's fibers, but there is no bone-implant contact. (Original magnification × 8; Stevenel's blue stain.)*

Discussion

Predictable osseointegration can be achieved with nonsubmerged, unloaded implants.[6,7] In a study of reconstruction of the edentulous mandible with titanium, plasma-sprayed screw implants, Babbush et al[8] reported a cumulative success rate of 87.96%. The implants were splinted using a Dolder bar 2 to 3 days after implant placement and the denture was placed with soft lining material. Clinical[9,10] as well as histologic[11,12] osseointegration was demonstrated with nonsubmerged, immediately loaded implants. Based on previous reports, splinting, with primary stabilization of individual implants, may bring implant micromovement below a critical level.[13]

In the present study, 10 of 18 MTIs placed in the posterior mandibles of dogs were successful and maintained clinical as well as histologic osseointegration. Of the 12 loaded implants 5 failed (41.6%), and 3 of 6 (50%) unloaded implants failed; thus, loading had no primary significant effect on implant failure. However, failure could be related to primary implant stabilization, as recorded by the Periotest. All failing implants were ranked as 1 and above, suggesting reduced initial stability.[14]

In view of the damage to the splints caused by uncontrolled mastication activity of the dogs, and in spite of repeated repairs, some implants may have lost their early splinting stabilization; thus, being exposed early to severe and parafunctional forces might have interrupted successful early stabilization and osseointegration. This might have been the case with the implant shown in Fig 7, in which osseointegration was not present by the end of the study; still, surrounding connective tissue was very thin and young, growing trabecular bone remodeling was present in close proximity (0.05 to 0.2 mm) to the implant surface.

Furthermore, periimplant bone resorption, especially around the most coronal part of the implant, might have occurred as a result of the method of insertion. According to the manufacturer's instructions, implants were inserted in the jaw via the mucosa. Thus, in spite of the careful cleansing of the mucosa with chlorhexidine, bacteria as well as soft tissue cells might have been driven into the bone. This new approach needs further investigation, mainly because no direct evidence to support these postulations has been found.

In this study, bone-to-implant contact ranged from 30% to 65%. Albrektsson and Jacobsson[15] suggested that an implant could be defined as osseointegrated if most of it is anchored in bone tissue. However, they stated that since the minimum degree of bone contact has not been defined interpretation could differ.

Because, to the best of the authors' knowledge, this is the first published histomorphometric study on MTIs, no comparative data were available. Our own preliminary, unpublished histomorphometric data in humans, as well as the data of Froum et al,[16] suggest between 40% and 72% bone-to-metal contact. It is therefore noteworthy to mention available data from animal studies in which regular implants were immediately loaded.

Steflik et al[17] compared 120 implants from 6 different implant systems supporting fixed partial dentures over 24 months; 24 implants were unloaded and served as controls. Their results indicated no significant difference between loaded and unloaded implants. The percentage of bone contact in a one-stage titanium implant system was 41%, which corresponds to the study of Cason et al,[18] which showed 45%. Higher percentages of bone contact with implants have been shown by Gottlander and Albrektsson,[19] who placed implants in rabbit tibias and found 76% bone contact with uncoated and 52.6% with hydroxyapatite-coated implants. In other studies, 46% to 60% implant-bone contact was measured.[20,21] In the present study the percentage of contact between the bone and the threaded portion of the implants was 30% to 65%, with a mean of 48.5% and no significant difference between loaded and unloaded implants. These results are consistent with other studies, although MTIs represent a completely different approach, ie, a transitional modular implant to be removed at a later stage rather than definitive implants to be restored permanently if successful.[22]

In a number of specimens some of the threaded portion of the implant could not be expected to be in contact with bone because it was located coronal to the crestal bone. Elimination of this factor increased the mean bone-to-implant contact to 55.5%. This observation is clinically significant; when MTIs are inserted through the mucosa, the mucosal width should be estimated to ensure complete penetration of the threaded portion into bone before placement.

The main difference between the failing loaded and unloaded implants was that the former presented a wider socket around the coronal part of the implant. Regardless of the reason for failing, the mobility of a nonintegrated implant that is affected by masticatory forces may result in more bone loss compared to a nonintegrated but unloaded implant. This observation has a clinical application; we recommend that if MTIs are used, they should be carefully monitored during their transitional period of function, and removal should be considered in the case of notable mobility.

In the present study implants were inserted in mandibular postextraction healing sites. Since no distinction was made as to whether each implant was inserted in a former healing extraction socket or in mature bone, it is logical that different implants were inserted in sites with different bone quality. In observing the histologic specimens, we were under the impression that failing implants were located in a relatively loose bone (Type III or IV), which thus presented a lower recording of initial stability, whereas osseointegrated implants were located in relatively denser bone (Type II).

Conclusions

In this study, 56% of the MTIs integrated and 44% failed, of which 2 (25%) exfoliated prior to termination of the study. Several reasons may have contributed to this relatively high failure rate:

1. Low quality of bone at the implant site, resulting in reduced initial anchorage (Periotest recordings above 1).
2. Uncontrolled load or uncontrolled nonfunctional animal activity, as indicated by the early and repeated damage to the acrylic resin splints.
3. A relatively excessive load. In this study only 2 MTIs served as abutments for each fixed partial denture, thus permitting a fulcrum line that resulted in a nonstabilized restoration in a buccolingual direction.
4. Insertion of the implants in the jaw via the mucosa might have driven bacteria and/or soft tissue components into the bone.

These possibilities—especially the first, third, and fourth—should be considered when applying the MTI system clinically.

Acknowledgments

The authors would like to thank Dr M. D. Rohrer, Oklahoma College of Dentistry for histologic assistance and advice. This study was supported in part by Dentatus, Sweden and by the Gerald Niznick Chair in Implant Dentistry at Tel Aviv University. Research was carried out in the Alpha Omega Laboratories, School of Dental Medicine, Tel Aviv University and Research Laboratories of the University of Oklahoma College of Dentistry.

References

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
2. Brånemark P-I. Osseointegration and its experimental background. J Prosthet Dent 1983;50:399–410.
3. Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985.
4. Donath K, Breuner G. A method for the study of undecalcified bones and teeth with attached soft tissues. The Saege-Schliff technique. J Oral Pathol 1982;11:318.
5. Rohrer MD, Schubert CC. The cutting-grinding technique for histological preparation of undecalcified bone and bone-anchored implants. Improvement in instrumentation and procedures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1992;74:73–78.
6. Schroeder A, Van der Zypen E, Stich H, Sutter F. The reaction of bone, connective tissue and epithelium to endosteal implants with sprayed titanium surface. J Maxillofac Surg 1981;9:15–25.

7. Buser DA, Schroeder A, Sutter F, Lang NP. The new concept of ITI hollow cylinder and hollow screw implants. Part 2. Clinical aspects, indications and early clinical results. Int J Oral Maxillofac Implants 1988;3:173–181.

8. Babbush CA, Kent JN, Misiek DJ. Titanium plasma sprayed screw implants for the reconstruction of the edentulous mandible. J Oral Maxillofac Surg 1986;44:274–282.

9. Schnitman PA, Wöhrle PS, Rubenstein JE. Immediate fixed interim prostheses supported by two-stage threaded implants: Methodology and results. J Oral Implantol 1990;16:96–105.

10. Wöhrle PS, Schnitman PA, DaSilva JD, Wang NH, Koch GG. Brånemark implants placed into immediate function: 5-year results (abstract). J Oral Implantol 1992;18:382.

11. Lum LB, Beirne OR, Curtis DA. Histologic evaluation of HA-coated versus uncoated titanium blade implants in delayed and immediately loaded applications. Int J Oral Maxillofac Implants 1991;6:456–462.

12. Sagara M, Yasumasa A, Hiromasa N, Hiromichi T. The effect of early occlusal loading on one stage titanium alloy implants in beagle dogs: A pilot study. J Prosthet Dent 1993;69:281–288.

13. Brunski JB. Avoid pitfalls of overloading and micromotion of intraosseous implants (interview). Dent Implantol Update 1993;4:77–81.

14. Chavez H, Ortman LF, DeFranco RL, Medig J. Assessment of oral implant mobility. J Prosthet Dent 1993;70:421–426.

15. Albrektsson T, Jacobsson M. Bone-metal interface in osseointegration. J Prosthet Dent 1987;57:597–607.

16. Froum S, Emtiaz S, Bloom MJ, Scolnick J, Tarnow DP. The use of transitional implants for immediate fixed temporary prostheses in cases of implant restorations. Pract Periodontics Restorative Dent 1998;10:737–752.

17. Steflik DE, Lake FT, Sisk AL, Parr GR, Hanes PJ, Davis HC, et al. A comparative investigation in dogs: 2-year morphometric results of the dental implant-bone interface. Int J Oral Maxillofac Implants 1996;11:15–25.

18. Cason L, McKinney RV, Larke V, Steflik DE. Histomorphometric analysis of endosteal implant bone interfaces (abstract 1,905). J Dent Res 1990;69:347.

19. Gottlander M, Albrektsson T. Histomorphometric studies of hydroxylapatite-coated and uncoated CP titanium threaded implants in bone. Int J Oral Maxillofac Implants 1991;6:399–404.

20. Parr GR, Steflik DE, Sisk AL. Histomorphometric and histologic observations of bone healing around immediate implants in dogs. Int J Oral Maxillofac Implants 1993;8:534–540.

21. Pilliar RM, Deporter DA, Watson PA, Pharoah M, Chapman M, Valiquette, et al. The effect of partial coating with hydroxylapatite on bone remodeling in relation to porous coated titanium alloy dental implants in the dog. J Dent Res 1991;70:1,338–1,345.

22. Schnitman PA, Wöhrle PS, Rubenstein JE, DaSilva JD, Wang NH. Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. Int J Oral Maxillofac Implants 1997;12:495–503.