The Use of Implant-Supported Ceramometal Titanium Prostheses Following Sinus Lift and Augmentation Procedures: A Clinical Report

Christine Knabe, Dr*/Bodo Hoffmeister, Prof Dr Dr**

This clinical report presents rationale and clinical procedures involved in the use of ceramometal implant-supported titanium-cast prostheses for the rehabilitation of patients with atrophic maxillae requiring iliac crest grafting procedures. Favorable clinical results have been obtained, although clinical observation periods have been limited. The present observations suggest that osseointegrated ceramometal titanium prostheses could form a valuable part of restorative therapy following augmentation procedures. Furthermore, these titanium prostheses may be a meaningful contribution to implant prosthodontics, facilitating restorations of optimum biocompatibility.
(INT J ORAL MAXILLOFAC IMPLANTS 1998;13:102–108)

Key words: atrophic maxilla, ceramometal titanium restorations, dental implants, iliac crest grafts, implant-supported prosthesis, Le Fort I osteotomy, sinus lift procedure

The therapeutic regimen for treating patients with missing teeth has been significantly expanded by modern implant methods. The prosthesis supported by osseointegrated implants has become an integral part of restorative therapy for both completely and partially edentulous patients.[1–5] However, a prerequisite for successful oral implants is sufficient jaw bone volume. Placement of implants in the dental alveolar crest of the maxilla is limited by the height of bone between the alveolar crest and the maxillary sinus and floor of the nose. Consequently, the use of osseointegrated implants in the atrophic maxilla is often restricted because of the lack of supporting bone. To overcome such problems, various augmentation procedures have been proposed for rehabilitation of patients with atrophic maxillae.[6] Sinus lift and augmentation procedures using iliac crest grafts with simultaneous placement of endosseous implants is a treatment modality for atrophic posterior maxillae.[6–9] The edentulous maxilla may be managed either by alveolar ridge augmentation with onlay iliac bone grafts and immediate implant placement,[6,7,10–13] or by Le Fort I osteotomy in conjunction with an interpositional iliac crest graft and immediate endosseous implants for severely atrophic maxillae.[14,15] With the latter method, advancement of the maxilla can be carried out simultaneously in patients where a considerable sagittal intermaxillary discrepancy has developed as a result of maxillary atrophy.[14,15]

Titanium is a highly attractive material for dental prostheses because of its excellent corrosion resistance and biocompatibility in the oral environment.[16,17] Other advantages are its light weight, high strength-to-weight ratio, and low thermal conductivity. To avoid galvanic effects, it has become desirable to use the same metal or dental alloy for all restorations placed in the oral cavity.[18] In this respect, titanium appears to be the material of choice for implant restorations. However, prosthodontic application of titanium first required the mastery of a number of technical problems, since it is highly reactive at high-

*Research Associate, Department of Restorative Dentistry and Periodontology, University Hospital Benjamin Franklin, Free University of Berlin, Berlin, Germany.
**Professor and Chair, Department of Maxillofacial Surgery, University Hospital Benjamin Franklin, Free University of Berlin, Berlin, Germany.

Reprint requests: *Dr Christine Knabe, Department of Restorative Dentistry and Periodontology, University Hospital Benjamin Franklin, Free University of Berlin, Aßmannshauser Str. 4-6, 14197 Berlin, Germany. Fax: 49-30-8290391.*

er temperatures. Because of its high melting point, low specific gravity, and reaction with oxygen at high temperatures, the casting of titanium has necessitated development of suitable casting machines and investment materials. Even with special casting methods, precision casting of titanium dental prostheses was subject to certain difficulties such as surface oxygen contamination and surface interaction with the investment, development of pores, and difficulties in obtaining a precise fit, especially with complicated structures.[19–21] Since osseointegrated implants are much less mobile than natural teeth, obtaining a precise fit with fixed implant-supported prostheses is of paramount importance to prevent excess loading of the surrounding bone.[22,23]

The problems associated with titanium casting led to the application of additional technologies such as CAD/CAM, laser welding, and spark erosion.[20,21,24] Only recent improvements in casting technology and investment materials have made it possible to produce titanium crown and fixed partial prostheses with about the same accuracy as that achieved in conventional restorative castings.[25] Another important issue that had to be considered when using titanium for esthetic crowns and fixed partial prostheses was the application of porcelain veneers. Because titanium undergoes transformation from a hexagonal close-packed alpha phase to a body-centered cubic beta phase at 882°C, and because it has a high affinity for oxygen, the porcelain should be fired at a temperature below 850°C to prevent excess oxide formation. Consequently, suitable low-fusing porcelains were developed.[20,21] However, a problem encountered with these porcelain veneering systems was the formation of an interfacial oxide layer during firing that affected the porcelain-titanium bonding and thus restricted clinical use. The thicker this layer, the weaker the bonding.[26,27] Further improvements in these veneering systems included application of special bonding agents.[20] Since data from recent in vitro studies have demonstrated sufficient bonding strength with these newly developed materials, their clinical application can be recommended.[28–30] Data from clinical studies have not been reported thus far.

As a result of these developments, ceramometal implant-supported titanium-cast restorations have been used in our department for prosthetic therapy of atrophic maxillae following augmentation procedures. These prostheses were used in combination with titanium crown and fixed partial prostheses supported by natural teeth for full-mouth rehabilitation of patients requiring a comprehensive treatment plan involving the combined efforts of maxillofacial surgery and prosthodontics.

Materials and Methods

Clinical Procedures. Since radiographic examination is of particular importance before endosseous implants are placed into severely resorbed alveolar ridges, computed tomography was used to accurately assess the amount of residual bone.[31] The restorative design was determined preoperatively by a diagnostic wax-up on articulated diagnostic casts. The wax-up was used to select the ideal location and angulation of implants with regard to the anticipated restorative design, and a surgical template was then fabricated accordingly.[32] If Le Fort I osteotomy was performed in conjunction with maxillary advancement, positioning of the maxilla and the anticipated occlusal plane were also determined by means of diagnostic casts and wax-up. In this manner, the restorative design rather than the anatomy dictated implant placement to achieve a favorable restorative result.

For reconstruction of edentulous atrophic maxillae, Le Fort I osteotomy, in combination with an interpositional bone graft and miniplate osteosynthesis, was followed by immediate placement of endosseous implants in a submerged manner using ITI-Bonefit screw implants (Straumann, Waldenburg, Switzerland). The horseshoe-shaped corticocancellous graft was harvested from the iliac crest. The atrophic posterior maxilla was treated by augmentation of the maxillary sinus floor with iliac crest block grafts and simultaneous implant placement, also using ITI-Bonefit screw implants.

After completion of a 5- to 6-month healing period, the implants were exposed by punching, and healing caps were placed.[33] Ten to 14 days later, abutment connection was carried out, and prosthetic treatment was initiated. Preference was given to the ITI-cone abutments with 6-degree taper.

The restorative therapy followed certain guidelines. In partially edentulous jaws, small-unit restorations and single-crown prostheses were generally used to avoid extensive blockage. Whenever possible, implant prostheses were kept separate from natural teeth. If tooth-to-implant fixed prostheses were used, a rigid design without any additional flexible element was applied. Whenever possible, a mutually protected occlusion was created. Occlusion in centric relation was carefully equilibrated to avoid premature and excessive contacts.

Cemented restorations were preferred. Titanium castings were fabricated using the Castmatic casting machine (Dentaurum, Pforzheim, Germany). For veneering, the low-fusing Vita Titanium Porcelain (Vita, Bad Säckingen, Germany) was applied. Final placement was achieved with zinc oxide phosphate cement.

Case Reports

Case 1. A 47-year-old man presented for prosthetic treatment with a severely atrophic maxilla providing little support for a complete denture (Fig 1a). In the mandible, the central incisors, premolars, and molars were missing with the exception of the mandibular right premolar, which was scheduled for extraction.

The comprehensive treatment plan included implant therapy, maxillofacial surgery, and fixed prosthodontics. In the mandible, implants were placed in the molar and premolar regions. Attempts to place an implant in the molar region of the left mandibular quadrant failed for lack of sufficient bone. Implant therapy to replace the central incisors had been performed by a private practitioner. The healing period for the mandible was followed by placement of provisional resin-veneered restorations. The atrophic maxilla was treated by Le Fort I osteotomy in conjunction with an interpositional iliac crest graft, maxillary advancement, miniplate osteosynthesis, and simultaneous placement of six endosseous implants. After completion of the 5-month healing period, second-stage surgery was performed to expose the implants. Definitive prosthetic treatment was then initiated after abutment connection. Angulated abutments were selected for the implants in the region of the maxillary incisors. Prosthetic reconstruction (Figs 1b and 1c) included placement of titanium-ceramic fixed prostheses in both of the maxillary quadrants. Implant-supported ceramometal restorations and crowns supported by natural teeth were placed in the right mandibular quadrant, and a fixed cantilever prosthesis, supported by a combination of teeth and osseointegrated titanium implants, was placed in the left mandibular quadrant.

Case 2. This 43-year-old man had a temporomandibular disorder, missing posterior teeth in the right maxillary quadrant, and an atrophic alveolar ridge. Premolars were missing in the left maxillary quadrant, and removal of the third molar was indicated. Subsequent loss of the vertical dimension of occlusion was noted. In the mandible, the first and second molars had been replaced by extensive restorations (Fig 2a).

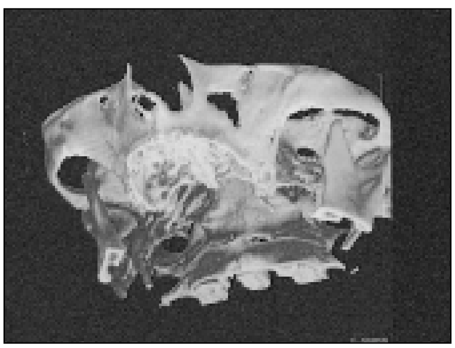


Fig 1a Patient 1. Three-dimensional visualization of the severely atrophic maxilla generated from CT scans taken preoperatively.

Fig 1b Patient 1. Frontal view with ceramometal restorations in situ.

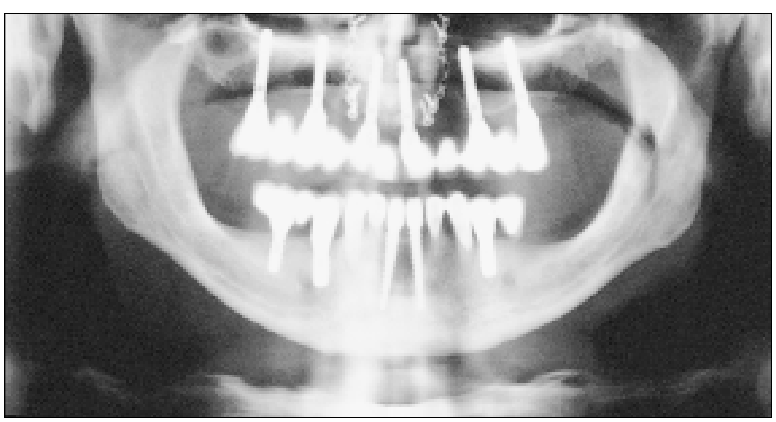


Fig 1c Patient 1. Panoramic radiograph taken after completion of prosthetic treatment.

The comprehensive treatment plan included functional therapy, maxillofacial surgery, and implant prosthodontics. Functional therapy involved splint therapy followed by provisional restorations to increase the vertical dimension. Successful completion of this initial treatment phase was followed by implant placement. In the right maxillary quadrant, sinus lift surgery was performed using an iliac crest block graft in combination with immediate implant placement. For definitive prosthetic restoration (Figs 2b to 2d), implant-supported ceramometal prostheses were placed in combination with single crowns. In the left maxillary quadrant, the single implant was connected to the adjacent molar.

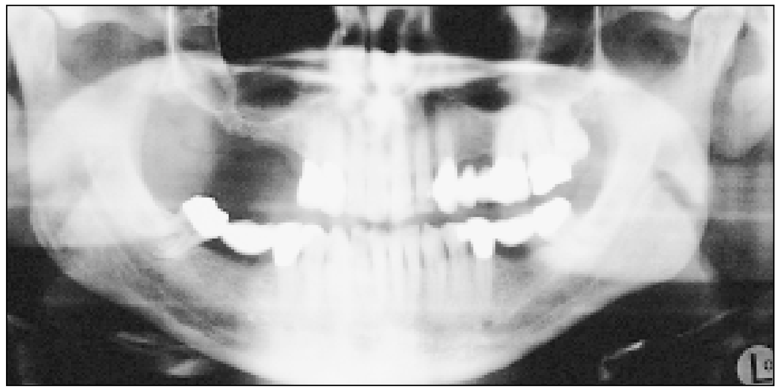
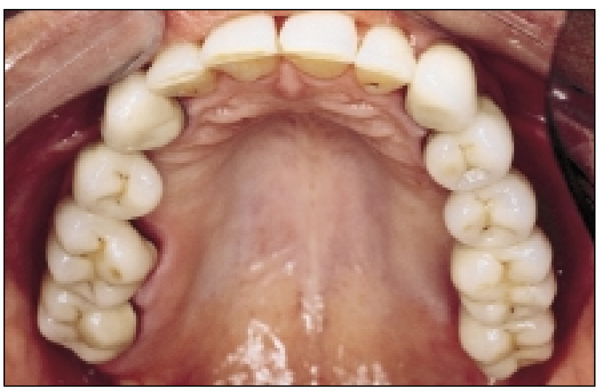
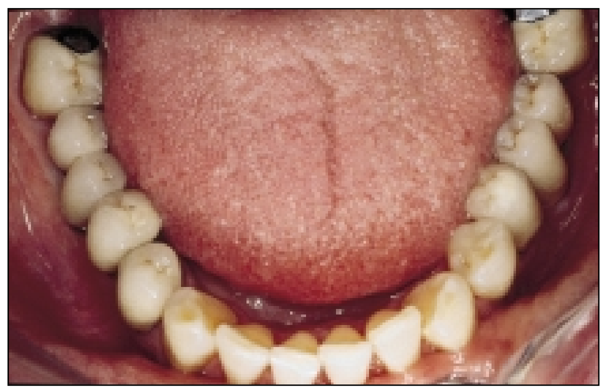


Fig 2a Patient 2. Panoramic radiograph taken preoperatively.





Figs 2b and 2c Patient 2. Occlusal view after placement of ceramometal restorations (photographs were taken in mirror).

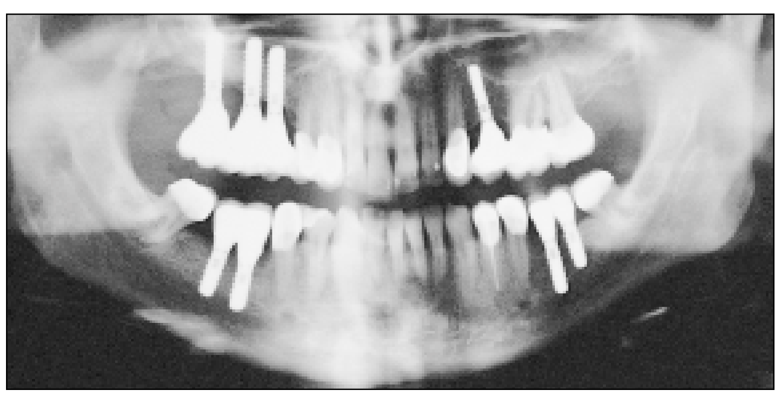


Fig 2d Patient 2. Panoramic radiograph after completion of prosthetic treatment.

Results

Healing was uneventful in both patients, who showed no clinical signs of infection. There was no inflammation of either the bone grafts or the maxillary sinuses. All implants were clinically stable at abutment connection. Follow-up examinations initially were carried out every 3 months and subsequently every 6 months. Radiographs were taken after definitive placement of restorations and then scheduled annually to monitor marginal bone loss. Complication-free serviceability of the titanium ceramometal restorations used in the cases presented has been observed for a period of up to 24 months. All implants followed up in these patients showed healthy peri-implant tissues without any remarkable changes in the pocket depth or Periotest values. No significant changes were noted with respect to periodontal health, ie, pocket depth, attachment level, or bleeding upon probing. Furthermore, stability of occlusion and articulation was maintained.

Discussion

This clinical report indicates that favorable treatment results can be achieved using titanium implant-supported restorations for patients with atrophic maxillae requiring comprehensive treatment. These findings are in accordance with observations in patients who received full-mouth rehabilitation of periodontally involved dentitions, also using osseointegrated titanium prostheses. In the latter patients, complication-free serviceability has been documented throughout an observation period ranging from 18 to 30 months. However, the observation periods have thus far been limited in both patient groups. Consequently, follow-up examinations on a regular basis and thorough documentation of these patients treated with titanium-ceramic fixed prostheses after reconstructive bone graft surgery are of paramount importance. Several aspects are of specific relevance in these cases.

Monitoring of marginal bone height has been proposed as an important criterion for evaluating implant success.[34] After bone graft augmentation procedures, an altered bone-remodeling potential and peri-implant bone responses differing from those in a nongrafted situation may be anticipated,[35] since iliac bone grafts are subjected to osteoconductive revitalization.[11] A study by Feifel et al[36] of mandibular bone density after iliac crest grafting using quantitative computerized tomography (QCT) revealed that nonvascularized grafts healed with a reactive sclerosis, an irregular reparative metaplastic process, and mineralization. Integration of the iliac bone grafts into the biodynamics of the jaw and early loading with physiologic forces have been recommended to avoid bone resorption.[37]

Bacterial studies of peri-implant microflora demonstrated different morphologic phenotypes when comparing the edentulous and partially dentate patient. Thus, periodontal pathogens from natural teeth may infect implant sites.[38,39] Furthermore, it has been stated that the immunologic capacity of the peri-implant soft tissue to react against bacterial endotoxins and exotoxins is inferior to that of the natural tooth because of reduced vascularization.[23,40] Also, an enhanced tendency towards plaque accumulation has been reported for commercially pure titanium when compared to porcelain or conventional dental alloys.[20] Whether these findings imply that partially dentate patients with implant restorations after reconstructive bone graft surgery are possibly at greater risk for peri-implant bone loss remains to be clarified by controlled clinical studies providing longitudinal data. These observations, however, emphasize the importance of periodontal maintenance and a strict regimen of oral hygiene.

Little is known about the effects of many treatment factors related to implant suprastructures, ie, restorative design and abutment selection, size, shape, or orientation, with regard to the biomechanical strains generated and their influences on alveolar bone responses and peri-implant bone loss. Despite their prosthodontic importance, the impact of systemic and local factors on alveolar bone responses to biomechanical strains has yet to be investigated.[41] As a result of impaired tactile function of osseointegrated implants, lack of precision in the occlusal rehabilitation might not be readily detected by patients with implant-supported prostheses.[23,42,43] Consequently, occlusion and articulation need to be regularly reexamined to avoid excessive and premature contacts, since their role as variables for peri-implant bone loss is thus far unknown.[44]

In the patients described above, small-unit restorations were preferred to avoid extensive splinting (of abutments), and implant-supported prostheses were kept separate from natural teeth whenever possible (fourth quadrant of patient 1; first, third, and fourth quadrants of patient 2). The rationale for this approach was that optimal tactile sensibility of the natural teeth would create favorable conditions with regard to oral function and oral hygiene maintenance, since both patients had a history of functional disturbance. Furthermore, this approach was considered advantageous because torsions and deformations of the mandible cannot be compensated by osseointegrated implants[23,45] and because it is more difficult to apply porcelain veneers to extensive frameworks than to short-span restorations.

Moreover, both mandibular third molars in patient 2 showed periodontal changes most likely attributable to stress generated by torsions and elastic deformations of the mandible, following application of an extensive framework for a fixed prosthesis in the posterior mandible that did not incorporate any stress-breaking. To facilitate placement of a fixed prosthesis extending over a small span, implants were placed in the region of the first and second molars, to provide additional abutments.

If tooth-to-implant fixed prostheses were used, a rigid design lacking any flexible elements was applied according to Rangert et al[46] and Richter[47] (third quadrant of patient 1 and second quadrant of patient 2). Richter[47] measured vertical forces on molar-positioned implants connected to a premolar by a fixed prosthesis. During chewing, lower load levels were recorded for implants than for teeth. Clenching in centric occlusion caused similar load levels for teeth and implants.

Specific factors need to be considered in fabricating implant superstructures from titanium by casting. From the surgical point of view, different implant systems, ie, different screw-form implant systems, could have been used in the cases described above. However, from a technical point of view, prefabricated gold alloy copings for the casting-on technique offered by many implant systems cannot be applied, since titanium does not bond to these copings. These difficulties can be avoided by using the ITI-cone abutments described above, because the same technical procedures can be applied as for the fabrication of crown and fixed partial prostheses, when natural teeth serve as abutments. As materials and technologies are developed, an increasing number of manufacturers might consider offering prefabricated, fully combustible plastic copings with their implant systems. These would be suitable for a burn-out technique, or titanium copings that are suitable for laser welding could be provided. These plastic copings could also be applied for the fabrication of cast titanium restorations, cemented as well as screw-retained restorations.

Conclusions

Implant-supported ceramometal titanium-cast prostheses can form a valuable part of restorative therapy for patients with atrophic maxillae requiring a combined therapeutic approach involving maxillofacial surgery and prosthetic treatment. Furthermore, titanium-ceramic fixed prostheses may be a meaningful contribution to implant prosthodontics, facilitating restorations of optimum biocompatibility.

Acknowledgments

The authors thank Mrs A. Laudien and Mr A. Hoffmann and the staff of H + H Dental Lab Inc, Moringen, Germany, for prosthesis fabrication.

References

1. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt TA. Long-term follow-up study of osseointegrated implants in the treatment of the totally edentulous jaw. Int J Oral Maxillofac Implants 1990;5:347–359.
2. Henry P, Tolman DE, Bolender S. The applicability of osseointegrated implants in the treatment of partially edentulous patients. Three-year results of a prospective multicenter study. Quintessence Int 1993;24:123–129.
3. Jemt T, Lekholm U. Oral implant treatment in posterior partially edentulous jaws: A 5-year follow-up report. Int J Oral Maxillofac Implants 1993;8:635–640.
4. 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.
5. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants in posterior partially edentulous patients. Int J Prosthodont 1993;6:189–196.
6. Tolman DE. Reconstructive procedures with endosseous implants in grafted bone: A review of the literature. Int J Oral Maxillofac Implants 1995;10:275–294.
7. Smiler DG. Surgical solutions to prosthetic problems. J Dent Symp 1993;1:44–49.
8. Raghoebar GM, Brouwer TJ, Reintsema H, van Oortt RP. Augmentation of the maxillary sinus floor with autogenous bone for the placement of endosseous implants: A preliminary report. J Oral Maxillofac Surg 1993;51:1198–1205.
9. Zinner ID, Small SA, Panno FV, Pines MS. Provisional and definitive prostheses following sinus lift and augmentation procedures. Implant Dent 1994;3:24–28.
10. Adell R, Lekholm U, Gröndahl K, Brånemark P-I, Lindström J, Jacobsson M. Reconstruction of severely resorbed edentulous maxillae using osseointegrated fixtures in immediate autogenous bone grafts. Int J Oral Maxillofac Implants 1990;5:233–246.
11. Isaksson S, Alberius P. Maxillary alveolar ridge augmentation with bone onlay-grafts and immediate endosseous implants. J Craniomaxillofac Surg 1992;20:2–7.
12. Weingart D, Schilli W, Strub JR. Severe atrophy of the alveolar ridge in edentulous patients. Combined treatment using bone grafts and screw implants. Rev Stomatol Chir Maxillofac 1992;93:214–217.
13. Nystrom E, Legrell PE, Forsell A, Kahnberg KE. Combined use of bone grafts and implants in the severely resorbed maxilla. Int J Oral Maxillofac Surg 1995;24:20–25.
14. Isaksson S, Ekfeldt A, Alberius P, Blomquiszt JE. Early results from reconstruction of severely atrophic (Class IV) maxillas by immediate endosseous implants in conjunction with bone grafting and Le Fort I osteotomy. Int J Oral Maxillofac Surg 1993;22:144–148.
15. Jänicke S, Pelster C, Schmitz H-J. Möglichkeiten, Grenzen und Probleme der Oberkieferinterpositionsosteoplastik mit simultaner Implantatversorgung. Z Zahnärztl Implantol 1994;10:161–166.
16. Fenton AH, Zarb GA. Research status of prosthodontic procedures. Int J Prosthodont 1993;6:137–144.

17. Könönen M, Rintanan J, Waltimo A, Kempainen P. Titanium framework removable partial denture used for patient allergic to other metals: A clinical report and literature review. J Prosthet Dent 1995;73:4–7.
18. Wirz J, Jäger K, Grande V. Einsatz von Titan in der implantatgestützten Teilprothetik. Quintessenz 1994;45:979–989.
19. Bessing C, Bergman M. The castability of unalloyed titanium in three different casting machines. Swed Dent J 1992;16:109–113.
20. Weber H, Pröbster L, Geis-Gerstorfer J. Titan als prothetischer Werkstoff. Dtsch Zahnärztl Z 1992;47:473–481.
21. Lautenschlager EP, Monaghan P. Titanium and titanium alloys as dental materials. Int Dent J 1993;43:245–253.
22. Meyer JM, Lüthy H. Titan in der Zahnheilkunde - Welche Entwicklungen gibt es heute? Quintessenz Zahntech 1995;21:681–712.
23. Schulte W. Implants and the periodontium. Int Dent J 1995;45:16–26.
24. Bergendal B, Palmquist S. Laser-welded titanium frameworks for fixed prostheses supported by osseointegrated implants: A 2-year multicenter study report. Int J Oral Maxillofac Implants 1995;10:199–206.
25. Wirz J. Titan - ein Werkstoff der modernen Prothetik. Quintessenz 1994;45:731–739.
26. Hautaniemi JA, Hero H, Juhanoja JT. On the bonding of porcelain on titanium. J Sci Mat Med 1992;3:180–191.
27. Moormann A. Vergleichende Untersuchung zum Titan-Keramik-Verbund. Zahnärztl Welt 1994;103:86–89.
28. Marx R, Maaß M, Vogelsang P. Bruchzähigkeit und Hydrolysebeständigkeit keramischer Massen für die Titanverblendung. Dtsch Zahnärztl Z 1992;47:516–521.
29. Eckmann S. Untersuchung zur Biegefestigkeit des Titan-Keramik-Verbundes bei Brücken in Abhängigkeit von der Oberflächenbearbeitung sowie zue Passgenauigkeit. - Eine in-vitro-Studie [dissertation thesis]. Berlin, Free Univ of Berlin, 1994.
30. Kruse N. Untersuchung zur Abscherfestigkeit des Titan-Keramik-Verbundes bei fünf titankeramischen Systemen in Abhängigkeit verschiedener Aufbrenntemperaturen - Eine in-vitro-Studie [dissertation thesis]. Berlin, Free Univ of Berlin, 1995.
31. Weingart D, Duker J. A tomographic technique for the depiction of atrophied alveolar ridges prior to endosseous implant placement. Dentomaxillofac Radiol 1993;22:38–40.
32. Lewis S, Parel S, Faulkner R. Provisional implant-supported fixed restorations. Int J Oral Maxillofac Implants 1995;10:319–325.
33. Sutter F, Weingart D, Mundwiler U, Sutter FJ, Askainen P. ITI implants in combination with bone grafts and biomechanical aspects. Clin Oral Implants Res 1994;5:164–172.
34. Smith DE, Zarb GA. Criteria for success of osseointegrated endosseous implants. J Prosthet Dent 1989;61:59–64.
35. Nystrom E, Kahnberg KE, Albrektsson T. Treatment of the severely resorbed maxillae with bone graft and titanium implants: Histologic review of autopsy specimens. Int J Oral Maxillofac Implants 1993;8:167–171.
36. Feifel H, Riediger D, Weiske R. Measurement of mandibular bone density after iliac crest grafting. J Oral Maxillofac Surg 1994;23:449–455.
37. Weingart D, Strub J, Schilli W. Kieferchirurgisch-prothetisches Konzept zur implantologischen Versorgung bei unterschiedlichem Atrophiegrad des zahnlosen Patienten. Z Stomatol 1992;3:137.
38. Apse P, Ellen RP, Overall CM, Zarb GA. Microbiota and crevicular collagenase activity in the osseointegrated dental implant sulcus: A comparison of sites in edentulous and partially edentulous patients. J Periodont Res 1989;24:96–105.
39. Quirynen M, Listgarten MA. The distribution of bacterial morphotypes around natural teeth and titanium implants ad modum Brånemark. Clin Oral Implants Res 1990;1:8–12.
40. Spiekermann H. Histopathologie. In: Rateischak KH, Wolf HF (eds). Farbatlanten der Zahnmedizin 10 - Implantologie. Stuttgart: Thieme, 1994:59–80.
41. Lavelle, CLB. Biomechanical considerations of prosthodontic therapy: The urgency of research into alveolar bone responses. Int J Oral Maxillofac Implants 1993;8:19–31.
42. Jacobs R, van Steenberghe D. Comparative evaluation of the oral tactile function by means of teeth or implant-supported prostheses. Clin Oral Implants Res 1991;2:75–80.
43. Spiekermann H. Das okklusale Konzept. In: Rateischak KH, Wolf HF (eds). Farbatlanten der Zahnmedizin 10 - Implantologie. Stuttgart: Thieme, 1994:299–304.
44. Zarb GA, Albrektsson T. Osseointegration: A requiem for the periodontal ligament. Int J Periodont Rest Dent 1991;11:88–91.
45. Solar P, Pleschberger M, Wiesinger S, Matjka M, Watzek G. Auslenkung von implantatgetragenem Zahnersatz durch die funktionelle Verformung der Mandibula. Z Zahnärtzl Implantol 1994;10:106–112.
46. Rangert B, Gunne J, Sullivan DY. Mechanical aspects of a Brånemark implant connected to a natural tooth: An in vitro study. Int J Oral Maxillofac Implants 1991;6:177–186.
47. Richter EJ. In vivo vertical forces on implants. Int J Oral Maxillofac Implants 1995;10:99–108.