

Literature

Titanium and its alloys in dental implantology

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1. Lemons JE. Dental implant biomaterials. J Am Dent Assoc 1939. 1990 Dec;121(6):716–9.
2. Parr GR, Gardner LK, Toth RW. Titanium: the mystery metal of implant dentistry. Dental materials aspects. J Prosthet Dent. 1985 Sep;54(3):410–4.
3. Lautenschlager EP, Monaghan P. Titanium and titanium alloys as dental materials. Int Dent J. 1993 Jun;43(3):245–53.
4. Wang RR, Fenton A. Titanium for prosthodontic applications: a review of the literature. Quintessence Int Berl Ger 1985. 1996 Jun;27(6):401–8.
5. Park, J.B. & Kim, Y.K. Metallic biomaterials. In: The Biomedical Engineering Handbook. 2nd ed. Vol. I. CRC Press and IEEE Press, ISBN 0- 8493-0461-X, Boca Raton, Florida, USA; 37-1–37-20 p.
6. Niinomi M, Nakai M. Titanium-Based Biomaterials for Preventing Stress Shielding between Implant Devices and Bone. Int J Biomater. 2011;2011:836587.
7. de Morais LS, Serra GG, Albuquerque Palermo EF, Andrade LR, Müller CA, Meyers MA, et al. Systemic levels of metallic ions released from orthodontic mini-implants. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2009 Apr;135(4):522–9.
8. Mohammed MT, Khan ZA, Siddiquee AN. Beta Titanium Alloys: The Lowest Elastic Modulus for Biomedical Applications: A Review. ResearchGate. 2014 Jan 1;8(8):726–31.
9. Caudill R, Vernino AR, Holt R, Severson S, Church C. Effect of unintentional exposure of 2-stage implants upon subsequent osseointegration: histologic findings 6 months postloading. Int J Periodontics Restorative Dent. 2000 Jun;20(3):307–14.
10. Müller FA, Bottino MC, Müller L, Henriques VAR, Lohbauer U, Bressiani AHA, et al. In vitro apatite formation on chemically treated (P/M) Ti-13Nb-13Zr. Dent Mater Off Publ Acad Dent Mater. 2008 Jan;24(1):50–6.
11. Siddiqi A, Payne AGT, De Silva RK, Duncan WJ. Titanium allergy: could it affect dental implant integration? Clin Oral Implants Res. 2011 Jul;22(7):673–80.
12. Müller K, Valentine-Thon E. Hypersensitivity to titanium: clinical and laboratory evidence. Neuro Endocrinol Lett. 2006 Dec;27 Suppl 1:31–5.
13. Egusa H, Ko N, Shimazu T, Yatani H. Suspected association of an allergic reaction with titanium dental implants: a clinical report. J Prosthet Dent. 2008 Nov;100(5):344–7.
14. Sicilia A, Cuesta S, Coma G, Arregui I, Guisasola C, Ruiz E, et al. Titanium allergy in dental implant patients: a clinical study on 1500 consecutive patients. Clin Oral Implants Res. 2008 Aug;19(8):823–35.
15. Cook SD, McCluskey LC, Martin PC, Haddad RJ. Inflammatory response in retrieved noncemented porous-coated implants. Clin Orthop. 1991 Mar;(264):209–22.
16. Tamai K, Mitsumori M, Fujishiro S, Kokubo M, Ooya N, Nagata Y, et al. A case of allergic reaction to surgical metal clips inserted for postoperative boost irradiation in a patient undergoing breast-conserving therapy. Breast Cancer Tokyo Jpn. 2001;8(1):90–2.
17. Fage SW, Muris J, Jakobsen SS, Thyssen JP. Titanium: a review on exposure, release, penetration, allergy, epidemiology, and clinical reactivity. Contact Dermatitis. 2016 Jun;74(6):323–45.
18. Javed F, Al-Hezaimi K, Almas K, Romanos GE. Is titanium sensitivity associated with allergic reactions in patients with dental implants? A systematic review. Clin Implant Dent Relat Res. 2013 Feb;15(1):47–52.
19. Harloff, T., Hönle, W., Holzwarth, U., Bader, R., Thomas, P. and Schuh, A. Titanium allergy or not? “Impurity” of titanium implant materials. Health (N Y). 2010;(2):306–10.

20. Chaturvedi T. Allergy related to dental implant and its clinical significance. *Clin Cosmet Investig Dent*. 2013 Aug 19;5:57–61.
21. Hallab N, Merritt K, Jacobs JJ. Metal sensitivity in patients with orthopaedic implants. *J Bone Joint Surg Am*. 2001 Mar;83-A(3):428–36.
22. Puleo DA, Nanci A. Understanding and controlling the bone-implant interface. *Biomaterials*. 1999 Dec;20(23–24):2311–21.
23. Kasemo B. Biological surface science. *Surf Sci*. 2002 Mar 10;500(1–3):656–77.
24. Liu X, Chu PK, Ding C. Surface modification of titanium, titanium alloys, and related materials for biomedical applications. *Mater Sci Eng R Rep*. 2004 Dec 24;47(3–4):49–121.
25. Bowers KT, Keller JC, Randolph BA, Wick DG, Michaels CM. Optimization of surface micromorphology for enhanced osteoblast responses in vitro. *Int J Oral Maxillofac Implants*. 1992;7(3):302–10.
26. Mustafa K, Wroblewski J, Hultenby K, Lopez BS, Arvidson K. Effects of titanium surfaces blasted with TiO₂ particles on the initial attachment of cells derived from human mandibular bone. A scanning electron microscopic and histomorphometric analysis. *Clin Oral Implants Res*. 2000 Apr;11(2):116–28.
27. Piattelli A, Manzon L, Scarano A, Paolantonio M, Piattelli M. Histologic and histomorphometric analysis of the bone response to machined and sandblasted titanium implants: an experimental study in rabbits. *Int J Oral Maxillofac Implants*. 1998 Dec;13(6):805–10.
28. Wennerberg A, Albrektsson T. Effects of titanium surface topography on bone integration: a systematic review. *Clin Oral Implants Res*. 2009 Sep;20 Suppl 4:172–84.
29. Sumner DR, Turner TM, Purchio AF, Gombotz WR, Urban RM, Galante JO. Enhancement of bone ingrowth by transforming growth factor-beta. *J Bone Joint Surg Am*. 1995 Aug;77(8):1135–47.
30. Puleo DA. Biochemical surface modification of Co-Cr-Mo. *Biomaterials*. 1996 Jan;17(2):217–22.
31. Nanci A, Wuest JD, Peru L, Brunet P, Sharma V, Zalzal S, et al. Chemical modification of titanium surfaces for covalent attachment of biological molecules. *J Biomed Mater Res*. 1998 May;40(2):324–35.
32. Mohan S, Baylink DJ. Bone growth factors. *Clin Orthop*. 1991 Feb;(263):30–48.
33. Lind M. Growth factor stimulation of bone healing. Effects on osteoblasts, osteomies, and implants fixation. *Acta Orthop Scand Suppl*. 1998 Oct;283:2–37.
34. Hasan J, Crawford RJ, Ivanova EP. Antibacterial surfaces: the quest for a new generation of biomaterials. *Trends Biotechnol*. 2013 May;31(5):295–304.
35. Fadeeva E, Truong VK, Stiesch M, Chichkov BN, Crawford RJ, Wang J, et al. Bacterial retention on superhydrophobic titanium surfaces fabricated by femtosecond laser ablation. *Langmuir ACS J Surf Colloids*. 2011 Mar 15;27(6):3012–9.
36. Tiller JC, Liao CJ, Lewis K, Klibanov AM. Designing surfaces that kill bacteria on contact. *Proc Natl Acad Sci U S A*. 2001 May 22;98(11):5981–5.
37. Jeng HA, Swanson J. Toxicity of metal oxide nanoparticles in mammalian cells. *J Environ Sci Health Part A Tox Hazard Subst Environ Eng*. 2006;41(12):2699–711.
38. Carpenter AW, Slomberg DL, Rao KS, Schoenfisch MH. Influence of scaffold size on bactericidal activity of nitric oxide-releasing silica nanoparticles. *ACS Nano*. 2011 Sep 27;5(9):7235–44.
39. Bornstein MM, Schmid B, Belser UC, Lussi A, Buser D. Early loading of non-submerged titanium implants with a sandblasted and acid-etched surface. 5-year results of a prospective study in partially edentulous patients. *Clin Oral Implants Res*. 2005 Dec;16(6):631–8.
40. van Velzen FJJ, Ofec R, Schulten EAJM, Ten Bruggenkate CM. 10-year survival rate and the incidence of peri-implant disease of 374 titanium dental implants with a SLA surface: a prospective cohort study in 177 fully and partially edentulous patients. *Clin Oral Implants Res*. 2015 Oct;26(10):1121–8.
41. Buser D, Janner SFM, Wittneben J-G, Brägger U, Ramseier CA, Salvi GE. 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched

- surface: a retrospective study in 303 partially edentulous patients. *Clin Implant Dent Relat Res.* 2012 Dec;14(6):839–51.
42. Cochran DL, Jackson JM, Bernard J-P, ten Bruggenkate CM, Buser D, Taylor TD, et al. A 5-year prospective multicenter study of early loaded titanium implants with a sandblasted and acid-etched surface. *Int J Oral Maxillofac Implants.* 2011 Dec;26(6):1324–
43. Buser D, Schenk RK, Steinemann S, Fiorellini JP, Fox CH, Stich H. Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. *J Biomed Mater Res.* 1991 Jul;25(7):889–902.
44. Klein MO, Bijelic A, Toyoshima T, Götz H, von Koppenfels RL, Al-Nawas B, et al. Long-term response of osteogenic cells on micron and submicron-scale-structured hydrophilic titanium surfaces: sequence of cell proliferation and cell differentiation. *Clin Oral Implants Res.* 2010 Jun;21(6):642–9.
45. Mesquita P, Gomes P de S, Sampaio P, Juodzbaly G, Afonso A, Fernandes MH. Surface properties and osteoblastic cytocompatibility of two blasted and Acid-etched titanium implant systems with distinct microtopography. *J Oral Maxillofac Res.* 2012;3(1):e4.
46. Rocuzzo M, Aglietta M, Bunino M, Bonino L. Early loading of sandblasted and acid-etched implants: a randomized-controlled double-blind split-mouth study. Five-year results. *Clin Oral Implants Res.* 2008 Feb;19(2):148–52.
47. Strietzel FP, Karmon B, Lorean A, Fischer PP. Implant-prosthetic rehabilitation of the edentulous maxilla and mandible with immediately loaded implants: preliminary data from a retrospective study, considering time of implantation. *Int J Oral Maxillofac Implants.* 2011 Feb;26(1):139–47.
48. Aybar B, Emes Y, Atalay B, Tanrikulu S, Kaya AS, İşsever H, et al. The influence of titanium surfaces in cultures of neonatal rat calvarial osteoblast-like cells: an immunohistochemical study. *Implant Dent.* 2009 Feb;18(1):75–85.
49. Sela MN, Badihi L, Rosen G, Steinberg D, Kohavi D. Adsorption of human plasma proteins to modified titanium surfaces. *Clin Oral Implants Res.* 2007 Oct;18(5):630–8.
50. Li D, Ferguson SJ, Beutler T, Cochran DL, Sittig C, Hirt HP, et al. Biomechanical comparison of the sandblasted and acid-etched and the machined and acid-etched titanium surface for dental implants. *J Biomed Mater Res.* 2002 May 1;60(2):325–32.
51. Artzi Z, Kohen J, Carmeli G, Karmon B, Lor A, Ormianer Z. The efficacy of full-arch immediately restored implant-supported reconstructions in extraction and healed sites: a 36-month retrospective evaluation. *Int J Oral Maxillofac Implants.* 2010 Apr;25(2):329–35.
52. Ormianer Z, Matalon S, Block J, Kohen J. Dental Implant Thread Design and the Consequences on Long-Term Marginal Bone Loss. *Implant Dent.* 2016 Aug;25(4):471–7.
53. Kohen J, Matalon S, Block J, Ormianer Z. Effect of implant insertion and loading protocol on long-term stability and crestal bone loss: A comparative study. *J Prosthet Dent.* 2016 Jun;115(6):697–702.
54. Elias C. N. Factors Affecting the Success of Dental Implants. *Implant Dentistry* 2011 319-364
55. Singh R. G. A comparative analysis of sandblasted and acid etched and polished titanium surface on enhancement of osteogenic potential: An in vitro study *Journal of Dental Implants* Jan - Jun 2012 Vol 2 Issue 1 15-18