ClinicSearch

Clinical Endocrinology and Metabolism

Massoud Attarian Shandiz *

Open Access

Review Article

Use of Dental Implants in Diabetic Patients. Review of Literature

Gagik Hakobyan [3]*, Hakob Khachatryan [1], Elena Aghajanova [2]

[1] Maxillofacial surgeon, Central clinical Military hospital (Ministry of Defence of The Republic of Armenia), Department of Oral and Maxillofacial Surgery, Yerevan State Medical University after M. Heratsi, Armenia

[2] Professor Head of Department of Endocrinology Yerevan State Medical University after M. Heratsi, Yerevan, Armenia

[3] Professor, Head of Department of Oral and Maxillofacial Surgery, Yerevan State Medical University after M. Heratsi, Armenia

*Corresponding Author: Gagik Hakobyan, Head of Department of Oral and Maxillofacial Surgery, Yerevan State Medical University, Yerevan State, Armenia.

Received date: January 19, 2024; Accepted date: January 29, 2024; Published date: February 01, 2024

Citation: Gagik Hakobyan, Hakob Khachatryan, Elena Aghajanova, (2024), Use of Dental Implants in Diabetic Patients. Review of Literature, *Clinical Endocrinology and Metabolism*, 3(2) **DOI:**10.31579/2834-8761/043

Abstract

Background: Prosthetic restoration with dental implants in diabetic patients has certain features, because in these patients, due to various factors, the osseointegration processes can be disrupted, in addition, in these groups of patients, the risk of peri-implantitis during functional load is also high.

Objective: The aim of this literature review was to summarize the influence of risk factors on dental implant failure in diabetic patients.

Methods: Search strategy was applied with the aim of identifying as many relevant publications as possible. Data Sources four electronic databases were searched: PubMed, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials.

The key words used for the search were dental implant failure risk factors, osteointegration failure risk factors, the use of implants, Implants in diabetic patients, use of photo functionalized implants in at-risk patients. Of the 146 studies identified, screening resulted in a further 54 articles being excluded for failure to report the specific cause of failure, leaving only 92 studies ultimately included in this review.

Results: Common risk factors for implant failure are related to patient history (radiation therapy, diabetes, periodontitis, use medications): any stage of the implantation treatment of patients of the risk group, an interdisciplinary approach should be taken, starting with planning and including long-term dynamic monitoring.

In this review, the author analyzes the prospect of using photo functionalized implants in patients with diabetic.

Conclusion: Patients with diabetes mellitus have a risk implant complication, but by maintaining glycemic control, supportive periodontal therapy, regular periodontal maintenance, and the use of photo functionalized implants, predictable results can be achieved and risks can be reduced.

Keywords: dental implants; photo functionalization; risk of implant failure; diabetic patients; glycemic control

Introduction

Along with the widespread use of dental implants in patients with various forms of teeth loss, literature reports the inability of osteointegration and peri-implantitis, especially in patients with risk.

These failures can be classified into early failure and late failure, failures occurring after the application of functional load [1].

The risk of implant failure includes general and local factors [2].

General factors include: the use of implants in patients with general somatic contraindications [3,4].

Local factors include: the presence of aggressive periodontitis in patient, residual inflammatory foci in the implantation area, osteoporosis, use of non-standardized implants, violation of sterility and contamination of the implant surface, violation of surgical standards (overheating of the bone during preparation, damage to anatomical structures, lack of primary stabilization, premature loading in case of contraindications) and oder [5,9].

Currently, one of the urgent tasks of implantology is to increase the efficiency of implantation in healthy compromised patients and one of the ways to solve is the manifestation of an interdisciplinary approach [10].

Patients with compromised healthy predisposition to various complications during both direct surgical intervention and in the long-term period and due to various factors (use medications, cancer therapy, smoking, bone ailments, decreased immunity, diabetes mellitus, impaired microcirculation, slow wound healing, age, and etc.) therefore, it is necessary to take precautions in various stages of implant treatment [11].

In practice, implantologists most often encounter patients with systemic diseases, among which the most common are patients use medications, endocrine disorders, including: diabetes mellitus, bone diseases: osteoporosis, etc. [12-16].

Among patients with endocrine diseases, most doctors encounter in implantology practice are patients with diabetes mellitus [18].

According to the International Diabetes Federation, the prevalence of diabetes has increased significantly over the past few decades and the federation predicts an increase in the incidence of diabetes.

Intraoral manifestations of diabetes mellitus are: aggressive periodontal disease, alveolar bone loss, salivary gland dysfunction, dry mouth, taste disturbances, fungal and bacterial infections, impaired healing of oral wounds, and tooth loss [19-22].

In patients with diabetes mellitus, microcirculation disorders lead to the regeneration of soft tissues of the oral cavity and bone healing processes are disrupted [23].

One of the most common lesions of the oral cavity in patients with diabetes is increased destruction of periodontal tissue as a result of impaired vascularization, decreased blood flow decreased function of polymorphonuclear leukocytes [24].

In patients with diabetes mellitus, tooth loss leads to poor digestion with poor metabolic control, this requires comprehensive prosthetic rehabilitation that will allow the patient to improve nutritional affect the success of dental implantation [25].

Due to resorption of the alveolar processes in diabetics with total edentulous prosthetic restoration with a conventional prosthesis is ineffective, who needs a dental implantation solved by more advanced methods.

The opinion on the use of dental implants in patients with diabetes is ambiguous for specialists, some consider diabetes relative contraindications, others do not share this opinion and believe that implants can be effectively used [26,27].

According to various publications, patients with diabetes have postoperative complications associated with implant deficiency and peri-implantitis after implant therapy [23,28,29].

According to Juliane Wagner et al. (2022) patients with poorly controlled diabetes have higher rates of peri-implantitis, and these patients have higher rates of implant loss in the long term than healthy individuals [30].

The process of osseointegration depends not only on the level of bone tissue metabolism, but also on the state of immune homeostasis of the oral mucosa of patients with implants [31].

With diabetes, the synthesis of protein is disturbed, the activity and maturation of osteoblasts is impaired, which operates bone mineralization in the surgical region and slows down the healing of the tissue [32,33].

In patients with diabetes mellitus, the growth and accumulation of extracellular bone matrix decreases, which leads to bone fragility, bone formation decreases during the healing process [34].

Patients with diabetes have an increased risk of fracture and, therefore, the use of drugs (for example, metformin), which has a useful effect on bone cells, can be one of the approaches to prevent the destruction of diabetic's bone [35].

Biochemical markers of bone formation and resorption tend to be lower in patients with diabetes [36].

According to G. Khachatryan and G. Hakobyan (2023), monitoring in the blood serum of patients with type 2 diabetes mellitus the concentration of bone metabolism markers osteocalcin and β-Cross-Laps can have prognostic significance for implants and will help the practitioner apply corrective drug therapy [37].

Violation concentration level biochemical markers of bone directly or indirectly affect the process of osseointegration, vascularization of the flap, can cause infection of soft tissues and slow down healing, which will affect the survival rate of dental implants and can lead to implant failure [38].

The prognosis of the results of dental implantation is also influenced by the presence of periodontitis and a decrease in the immune response in patients with diabetes mellitus, which increases the prevalence of postoperative infection and contributes to peri-implantitis [39-41]. However, there are scientific publications that report that successful osseointegration of a dental implant can be achieved in patients with diabetes with good metabolic control [42,43]. In patients with diabetes mellitus, protocols developed in general surgical practice are used, which include the following: control diet and hypoglycemic drugs, special aseptic methods and strict antibiotic prophylaxis [44-46].

Despite the increased risk, dental implantation remains the optimal treatment option for diabetes mellitus, allowing patients to regain chewing function and thereby expand their food choices, which can have a positive effect on digestion.

Thus, glycemic control and optimization of osseointegration is one of the main factors for long- term effective implantation therapy in patients with diabetes mellitus. Thus, for successful implantation in patients with diabetes, it is only necessary to adhere to the general surgical protocol for patients in this category, but also to improve osseointegration [47].

To improve osseointegration and increase the efficiency of bone-implant contact, biomedical research is aimed at modifying the implant surface [48].

Currently, various methods are used to modify the surface of titanium implants, this leads to increase the area of contact with the bone [49]. Modification of the implant surface improves the hydrophilicity of the surface, which enhances cell migration, thereby accelerating the process of osseointegration [50].

Surface modification methods include plasma surface, oxidation or additive processes, surface acid treatment (SLA), micro-arc oxidation, vacuum procedures, physical methods: alkaline heat treatment (AH) and laser melting [51-55].

Currently, UV irradiation, or photo functionalization, is one of the methods for treating the implant surface that improves the process of osseointegration [56,57].

Photo functionalization causes the formation of an electrostatic state of the titanium surface, transformation of the surface from hydrophobic to super hydrophilic, activation of protein absorption, and increased activity of fibroblasts and osteoblasts [58-62]. Changes in the properties of the implant surface following photo functionalization and the impact on implantation success, healing time, rate of osseointegration and changes in the level of marginal bone around the implant were first studied in clinical cases by Akiyoshi Funato and Takahiro Ogawa in 2013[63].

Photo functionalization of implant surfaces effective method for optimizing osseointegration [64-66].

One of the main factors causing implantation failure is the adhesion of microorganisms to dental implants, the components releasing which can stimulate inflammatory reactions in the peri-implant tissues [67-73].

UV irradiation not only improves the adhesion of osteoblasts on the surface of titanium implants, but also has an antimicrobial effect, reduces the amount of attachment/accumulation of bacteria and their components on the surface of the implant [74-86].

This can have an antimicrobial effect, thereby playing an important role in the complex of prevention and prevention of peri-implantitis [87-92].

The use of photofunctionalized implants in diabetic patients can increase the effectiveness of prosthetic treatment and reduce the risk of complications. However, long-term multicenter studies are needed to determine whether

photo functionalization reduces the risk of peri-implant complications and can play a preventive role in peri-implant complications in diabetic patients.

Conclusion

Patients with diabetes mellitus have a risk implant complications, but by maintaining glycemic control, supportive periodontal therapy, regular periodontal maintenance, and the use of photo functionalized implants, predictable results can be achieved and risks can be reduced.

Declaration

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article

Competing Interest

The author declares that he has no competing Interest. None of the authors have relevant financial relations with a commercial interest.

Funding

The work was not funded.

Acknowledgements

The author acknowledge scientific advisor professor Gagik Hakobyan, Head of Department of Oral and Maxillofacial Surgery, University of Yerevan State Medical University, Yerevan State, Armenia for cconceptualization and final revue.Authors read and approved the final manuscript**.**

References

1. Esposito, M.; Hirsch, J.M.; Lekholm, U.; Thomsen, P. (1998). Biological factors contributing to failures of osseointegrated oral implants, (I). Success criteria and epidemiology. *Eur. J. Oral Sci*, *106*, 527–551.
2. Alsaadi, G.; Quirynen, M.; Komárek, A.; Van Steenberghe, (**2008).** D. Impact of local and systemic factors on the incidence of late oral implant loss. *Clin. Oral Implant. Res*, *19*, 670–676.
3. Gómez-de Diego, R.(**2014)**Indications and contraindications of dental implants in medically compromised patients: Update. *Med. Oral Patol. Oral Cir. Bucal*,
4. Manzano, G.; Montero, J.; Martín-Vallejo, J.; Del Fabbro, M.; Bravo. *ET ALL.*, (**2016).** Risk factors in early implant failure: A meta-analysis. *Implant Dent*, *25*, 272–280
5. Lee DW. (2014). Periodontitis and dental implant loss. *Evid Based Dent.*Jun;15(2):59-60
6. Sgolastra F, Petrucci A, Severino M, Gatto R, Monaco A. (2015). Periodontitis, implant loss and peri-implantitis. A meta-analysis. *Clin Oral Implants Res.*Apr;26(4): e8-e16.
7. Sakka, S.; Baroudi, K.; Nassani, M.Z. (**2012).** Factors associated with early and late failure of dental implants. *J. Investig. Clin. Dent*, *3*, 258–261
8. Chrcanovic, B.R.; Kisch, J.; Albrektsson, T.; Wennerberg, A. (**2017).** Bruxism and dental implant treatment complications: A retrospective comparative study of 98 bruxer patients and a matched group. *Clin. Oral Implant. Res*, *28*, e1–e9.
9. Ferreira SD, Martins CC, Amaral SA, Vieira TR, Albuquerque BN, *ET ALL.*, (2018). Esteves Lima RP, Costa FO. Periodontitis as a risk factor for peri-implantitis: Systematic review and meta-analysis of observational studies. *J Dent.* Dec; 79:1-10.
10. Gheorghiu IM, Stoian IM. (2014). Implant surgery in healthy compromised patients-review of literature. *J Med Life;*7 Spec No. 2(Spec Iss 2):7-10.
11. Bornstein MM, Cionca N, Mombelli A. (2009). Systemic conditions and treatments as risks for implant therapy. *Int J Oral Maxillofac Implants*;24(Suppl):12–27
12. Dvorak, G.; Arnhart, C.; Heuberer, S.; Huber, C.D.; Watzek, G.; *ET ALL.*, (**2011).** Peri-implantitis and late implant failures in postmenopausal women: A cross-sectional study. *J. Clin. Periodontol*, *38*, 950–955.
13. Bornstein MM, Cionca N, Mombelli A. (2009). Systemic conditions and treatments as risks for implant therapy. *Int J Oral Maxillofac Implants*;24(Suppl):12–27
14. Courtney MW Jr, Snider TN, Cottrell DA. (2010). Dental implant placement in type II diabetics: a review of the literature. *J Mass Dent Soc.* Spring;59(1):12–14.
15. van Steenberghe D, Quirynen M, Molly L, Jacobs R. (*2003*). Impact of systemic diseases and medication on osseointegration. *Periodontol 2000*; 33:163–171
16. Mombelli A, Cionca N. (2006). Systemic diseases affecting osseointegration therap. *Clin Oral Implants Res.* Oct;17(Suppl 2):97–103
17. Glösel B, Kuchler U, Watzek G, Gruber R. (*2010*). Review of dental implant rat research models simulating osteoporosis or diabetes. *Int J Oral Maxillofac Implants.* May-Jun;25(3):516–524.
18. Javed F, Romanos GE. (2009). Impact of diabetes mellitus and glycemic control on the osseointegration of dental implants: a systematic literature review. *J Periodontol.* Nov;80(11):1719–1730
19. Mauri-Obradors E, Estrugo-Devesa A, Jané-Salas E, Viñas M, López-López J. (2017). Oral manifestations of Diabetes Mellitus. A systematic review. *Med Oral Patol Oral Cir Bucal.* Sep 1;22(5):e586-e594.
20. Lamster IB, Lalla E, Borgnakke WS, Taylor GW. (2008). The relationship between oral health and diabetes mellitus. *J Am Dent Assoc.* Oct;139 Suppl:19S-24S.
21. Salvi GE, Carollo-Bittel B, Lang NP. (2008). Effects of diabetes mellitus on periodontal and peri-implant conditions: update on associations and risks. *J Clin Periodontol.* Sep;35(8 Suppl):398–409.
22. Poskerová H, Linhartová PB, Hollá LI. (2019). Oral diseases in diabetic patients. Vnitr Lek. *Spring;* 65(4):314-320. English. PMID: 31091953.
23. Retzepi M, Donos N. (2010). The effect of diabetes mellitus on osseous healing. *Clin Oral Implants Res.*Jul;21(7):673–681
24. Courtney MW Jr, Snider TN, Cottrell DA. (2010). Dental implant placement in type II diabetics: a review of the literature. *J Mass Dent Soc.* Spring;59(1):12–14
25. Bukhary DM. (2023). Teeth Rehabilitation and Nutritional Influence on Diabetic Patients: A Review. Cureus. Sep 29;15(9): e46182.
26. Oates TW, Huynh-Ba G, Vargas A, Alexander P, Feine J. A (2013). critical review of diabetes, glycemic control, and dental implant therapy. *Clin Oral Implants Res.*Feb;24(2):117-127.
27. Alzahrani AS, Abed HH. (2016). To what extent should dental implant placement be adopted as a standard for diabetic patients? *Saudi Med J.* Nov;37(11):1179-1183.
28. Naujokat H, Kunzendorf B, Wiltfang J. (2016). Dental implants and diabetes mellitus-a systematic review. *Int J Implant Dent.* Dec;2(1):5.
29. Michaeli E, Weinberg I, Nahlieli O. (2009). Dental implants in the diabetic patient: systemic and rehabilitative considerations. *Quintessence Int.* Sep;40(8):639-645.
30. Wagner J, Spille JH, Wiltfang J, Naujokat H. (2022). Systematic review on diabetes mellitus and dental implants: an update. *Int J Implant Dent.* Jan 3;8(1):1.
31. Amengual-Peñafiel L, Córdova LA, Constanza Jara-Sepúlveda M, Brañes-Aroca M, Marchesani-Carrasco F, et all., (2021). Osteoimmunology drives dental implant osseointegration: A new paradigm for implant dentistry. *Jpn Dent Sci Rev.* Nov; 57:12-19.
32. Lee JWY, Bance ML. (2019). Physiology of Osseointegration. Otolaryngol *Clin North Am.* Apr;52(2):231-242.

33. KO, ANTON SCULEAN , DANA T. GRAVE Diabetic wound healing in soft and hard oral tissues Translational Research.2021,236;72-86
34. Murray CE, Coleman CM. (2019). Impact of Diabetes Mellitus on Bone Health. *Int J Mol Sci.* Sep 30;20(19):4873.
35. Jiao H, Xiao E, Graves DT. (2015). Diabetes and Its Effect on Bone and Fracture Healing. *Curr Osteoporos Rep.* Oct;13(5):327-335.
36. Christian Meier et al (2023). Biochemical Markers of Bone Fragility in Patients With Diabetes The *Journal of Clinical Endocrinology & Metabolism, Volume* 108, Issue 10, October e923–e936,
37. Hakob Khachatryana, Gagik Hakobyan. (2023). Diagnostic and prognostic value of indicators of markers of bone metabolism in type 2 diabetes mellitus patients with UV functionalized dental Implants"Hakob Khachatryana,Gagik Hakobyan. *Journal of Stomatology,* Oral and Maxillofacial Surgery;124, (6)101608
38. Alberti A, Morandi P, Zotti B, Tironi F, Francetti L, et all., (2020). Influence of Diabetes on Implant Failure and Peri-Implant Diseases: A Retrospective Study. *Dent J (Basel).* Jul 4;8(3):70.
39. Luigi Nibali, Nikolaos Gkranias, Giuseppe Mainas, Antonino Di Pino. (2022). Periodontitis and implant complications in diabetes. *Periodontology* 2020; 90-1,88-105
40. Zhao M, Xie Y, Gao W, Li C, Ye Q, et all., (2023). Diabetes mellitus promotes susceptibility to periodontitis-novel insight into the molecular mechanisms. *Front Endocrinol (Lausanne).* Aug 16; 14:1192625.
41. Chrcanovic BR, Albrektsson T, Wennerberg A. (2014). Diabetes and oral implant failure: a systematic review. *J Dent Res.*Sep;93(9):859-867.
42. Javed F, Romanos GE. (2009). Impact of diabetes mellitus and glycemic control on the osseointegration of dental implants: a systematic literature review. *J Periodontol.* Nov;80(11):1719-30.
43. Oates TW, Huynh-Ba G. Diabetes Effects on Dental Implant Survival. Forum Implantol. (2012). Feb;8(2):7-14. PMID: 25328546;
44. Wang A et al. (2020). Guidelines on multidisciplinary approaches for the prevention and management of diabetic foot disease (2020 edition). *Burns Trauma*. Jul 6;8: tkaa017.
45. Gheorghiu IM, Stoian IM. (2014). Implant surgery in healthy compromised patients-review of literature. *J Med Life*;7 Spec No. 2(Spec Iss 2):7-10. PMID: 25870664;
46. Sykara M, Maniatakos P, Tentolouris A, Karoussis IK, Tentolouris N. (2022). The necessity of administrating antibiotic prophylaxis to patients with diabetes mellitus prior to oral surgical procedures-a systematic review. Diabetes Metab Syndr. Oct;16(10):102621.
47. Sudhakaran S, Surani SR. (2015). Guidelines for Perioperative Management of the Diabetic Patient. *Surg Res Pract*; 2015:284063.
48. Chang LC. (2022). Clinical Applications of Photo functionalization on Dental Implant Surfaces: A Narrative Review. *J Clin Med.* Sep 30;11(19):5823.
49. Paul V, Mathew TA, Rasheed N, Thomas AS, George N. (2023). Photofunctionalization of Dental Implant Surfaces - A Histomorphometric Animal Study. *J Pharm Bioallied Sci.* Jul;15(Suppl 1): S646-S650.
50. Ghassemi A.et al. (2018). Biological and Physicochemical Characteristics of 2 Different Hydrophilic Surfaces Created by Saline-Storage and Ultraviolet Treatment. *Implant Dent.*;27:405–414.
51. Lee, H., Jeon, H.J., Jung, A. *et al.* Improvement of osseointegration efficacy of titanium implant through plasma surface treatment. *Biomed. Eng. Lett.* **12**, 421–432 (2022).
52. Zhao X, You L, Wang T, Zhang X, Li Z, ET ALL., (2020). Enhanced Osseointegration of Titanium Implants by Surface Modification with Silicon-doped Titania Nanotubes. Int J Nanomedicine. Nov 3; 15:8583-8594.
53. Chen M, Zhang Y, Driver MS, Caruso AN, Yu Q, et all., (2013). Surface modification of several dental substrates by non-thermal, atmospheric plasma brush. Dent Mater;29:871–880.
54. Chou WC, Wang RCC, Huang CL, Lee TM. (2018). The effect of plasma treatment on the osseointegration of rough titanium implant: A histo-morphometric study in rabbits. *J Dent Sci.*; 13:267–273.
55. Chou WC, Wang RCC, Liu C, Yang CY, Lee TM. (2017). Surface modification of direct-current and radio-frequency oxygen plasma treatments enhance cell biocompatibility. *Materials;* 10:1223.
56. Tabuchi M, Ikeda T, Nakagawa K, Hirota M, Park W, et al. (2015). Ultraviolet photofunctionalization increases removal torque values and horizontal stability of orthodontic miniscrews. *Am J Orthod Dentofacial Orthop*; 148:274–282
57. Choi B, Lee YC, Oh KC, Lee JH. (2021). Effects of photofunctionalization on early osseointegration of titanium dental implants in the maxillary posterior region: a randomized double-blinded clinical trial. *Int J Implant Dent.* May 10;7(1):37.
58. Hori N., Ueno T., Minamikawa H., Iwasa F., Yoshino F., Kimoto et all., (2010). Electrostatic Control of Protein Adsorption on UV-Photofunctionalized Titanium. *Acta Biomater*; 6:4175–4180.
59. Ikeda T, Okubo T, Saruta J, Hirota M, Kitajima H, et all., (2021). Osteoblast Attachment Compromised by High and Low Temperature of Titanium and Its Restoration by *UV Photo functionalization.* Materials (Basel). Sep 23;14(19):5493.
60. Pyo S-W, Park YB, Moon HS, Lee J-H, Ogawa T. (2013). Photofunctionalization enhances bone-implant contact, dynamics of interfacial osteogenesis, marginal bone seal, and removal torque value of implants: a dog jawbone study. *Implant dentistry*;22(6):666–675.
61. Yamauchi R, Itabashi T, Wada K, Tanaka T, Kumagai G, et all., (*2017*). Photofunctionalised Ti6Al4V implants enhance early phase osseointegration. *Bone & Joint Research*;6(5):331–336.
62. Hayashi M, Jimbo R, Xue Y, Mustafa K, Andersson M, et all., (2014). Photocatalytically induced hydrophilicity influences bone remodelling at longer healing periods: a rabbit study. *Clinical Oral Implants Research*;25(6):749–754.
63. Akiyoshi Funato, Takahiro Ogawa. (2013). Photofunctionalized Dental Implants: A Case Series in Compromised Bone**.** The. 28(6):1589-1601**;**
64. Ghambaryan, N., Jilavyan, A., Burnazyan, S. *et al.* Clinical Outcome of Immediate Loading UV-Photofunctionalized Implants in Patients with Completely Edentulous Mandible, Placed with Guided Surgery. *J. Maxillofac. Oral Surg.* **22** (Suppl 1), 64–75 (2023).
65. Vafadoost R, Shabahangfar MR, Khoshzaban A, Ahmadian Moghadam H. (2022). Histomorphic Analysis of UV-C Radiation on Osseointegration of Titanium Implants in the Rabbits. *J Dent (Shiraz).* Dec;23(4):489-497.
66. Choi, B., Lee, Y.C., Oh, K.C. *et al.* (2021).Effects of photofunctionalization on early osseointegration of titanium dental implants in the maxillary posterior region: a randomized double-blinded clinical 67/trial. *Int J Implant Dent* **7**, 37
67. Kitajima H, Ogawa T. (2016). The use of photofunctionalized implants for low or extremely low primary stability cases. *Int J Oral Maxillofac Implants*; 31:439–447.
68. Barão VAR, Costa RC, Shibli JA, Bertolini M, Souza JGS. (2022). Emerging titanium surface modifications: The war against polymicrobial infections on dental implants. *Braz Dent J.* Jan-Feb;33(1):1-12.
69. de Waal YC, Eijsbouts HV, Winkel EG, et al. (2017). Microbial Characteristics of Peri-Implantitis: A Case-Control Study. J Periodontol; 88:209-217.

70. Sahrmann P, Gilli F, Wiedemeier DB, et al. (2020). The Microbiome of Peri-Implantitis: A Systematic Review and Meta-Analysis. Microorganisms; 8:661.
71. Belibasakis GN, Manoil D. (2021). Microbial Community-Driven Etiopathogenesis of Peri-Implantitis. J Dent Res; 100:21-28
72. in CY, Chen Z, Pan WL, et al. (2020). Is History of Periodontal Disease Still a Negative Risk Indicator for Peri-implant Health Under Supportive Post-implant Treatment Coverage? A Systematic Review and Meta-analysis. *Int J Oral Maxillofac Implants*; 35:52-62.
73. Abdullatif FA, Al-Askar M. (2022). Does Ultraviolet Radiation Exhibit Antimicrobial Effect against Oral Pathogens Attached on Various Dental Implant Surfaces? A Systematic Review. Dent J (Basel). May 31;10(6):93.
74. Ryo SHIRAI et al. (2016). Antimicrobial effect of titanium dioxide after ultraviolet irradiation against periodontal pathogen. *Dental Materials Journal.* 35; 3 ;511-516
75. Yadav A, Yadav R, Gupta A, Baranwal A, Bhatnagar A, et all., (2017). Effect of Ultraviolet Irradiation on the Osseointegration of a Titanium Alloy with Bone. Contemp Clin Dent. Oct-Dec;8(4):571-578.
76. Binns R., Li W., Wu C.D., Campbell S., Knoernschild K., Yang B. (2020). Effect of Ultraviolet Radiationon Candida albicans Biofilmon Poly(methylmethacrylate) Resin. *J. Prosthodont.-Implant. Esthet. Reconstr. Dent*; 29:686–692.
77. Ishijima M., De Avila E.D., Nakhaei K., Shi W., Lux R., et all., (2019). Ultraviolet Light Treatment of Titanium Suppresses Human Oral Bacterial Attachment and Biofilm Formation: A Short-Term In Vitro Study. *Int. J. Oral Maxillofac. Implant*; 34:1105–1113.
78. Yamada Y., Yamada M., Ueda T., Sakurai K. (2014). Reduction of biofilm formation on titanium surface with ultraviolet-C-pre-irradiation. *J. Biomater. Appl*; 29:161–171.
79. Shirai R., Miura T., Yoshida A., Yoshino F., Ito T., et all., (*2016*). Anctimicrobial effect of titanium dioxide after ultraviolet irradiation against periodontal pathogen. *Dent. Mater. J* ;35:511–516.
80. Johnson H.A., Williamson R.S., Marquart M., Bumgardner J.D., Janorkar A.V., ET ALL., (2020). Photocatalytic activity and antibacterial efficacy of UVA-treated titanium oxides. *J. Biomater. Appl*; 35:500–514.
81. Dini C., Nagay B.E., Cordeiro J.M., da Cruz N.C., Rangel E.C., et all., (2020). Barao V.A. UV-photofunctionalization of a biomimetic coating for dental implants application. *Mater. Sci. Eng. C-Mater. Biol. Appl*; 110:110657.
82. Kligman S, Ren Z, Chung CH, Perillo MA, Chang YC, et all., (2021). The Impact of Dental Implant Surface Modifications on Osseointegration and Biofilm Formation. *J Clin Med.* Apr 12;10(8):1641.
83. Erica Dorigatti de Avila et alEffect of UV-photofunctionalization on oral bacterial attachment and biofilm formation to titanium implant Biomaterials.2015; 67;84-92
84. Yang Y., Zhou J., Liu X., Zheng M., Yang J., et all., (*2015*). Ultraviolet light-treated zirconia with different roughness affects function of human gingival fibroblasts in vitro: The potential surface modification developed from implant to abutment. *J. Biomed Mater. Res. B Appl. Biomater*; 103:116–124
85. Suzumura T, Matsuura T, Komatsu K, Sugita Y, Maeda H, et all., (2023). Vacuum Ultraviolet (VUV) Light Photofunctionalization to Induce Human Oral Fibroblast Transmigration on Zirconia. Cells. Oct 29;12(21):2542.
86. Chang LC. (2022). Clinical Applications of Photofunctionalization on Dental Implant Surfaces: A Narrative Review. *J Clin Med*. Sep 30;11(19):5823.
87. Sanchez-Perez A., Cachazo-Jimenez C., Sanchez-Matas C., Martin-de-Llano J.J., Davis S., (2020). Carda-Batalla C. Effects of Ultraviolet Photoactivation on Osseointegration of Commercial Pure Titanium Dental Implant After 8 Weeks in a Rabbit Model. *J. Oral. Implantol*;46:101–107.
88. Pyo S.W., Park Y.B., Moon H.S., Lee J.H., Ogawa T. (2013). Photofunctionalization enhances bone-implant contact, dynamics of interfacial osteogenesis, marginal bone seal, and removal torque value of implants: A dog jawbone study. *Implant Dent*; 22:666–675.
89. Sugita Y., Honda Y., Kato I., Kubo K., Maeda H., et all., (2014). Role of photofunctionalization in mitigating impaired osseointegration associated with type 2 diabetes in rats. *Int. J. Oral. Maxillofac. Implant*; 29:1293–1300.
90. Yamazaki M., Yamada M., Ishizaki K., Sakurai K. (2015). Ultraviolet-C irradiation to titanium implants increases peri-implant bone formation without impeding mineralization in a rabbit femur model. *Acta Odontol. Scand*; 73:302–311.
91. Yin C., Zhang T., Wei Q., Cai H., Cheng Y., et all., (*2022*). Surface treatment of 3D printed porous Ti6Al4V implants by ultraviolet photofunctionalization for improved osseointegration. *Bioact. Mater*; 7:26–38.