Recent Advances in Implant Biomaterials - A Review

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ABSTRACT
Usage of Implants in dentistry is tremendously increasing in recent times. This has led to the invention of new biomaterials for dental implants by the researchers. Continuous evolution has occurred in the field of dental implant biomaterials in the last two decades leading to the emergence of innovative biomaterials. This article summarizes the different implant biomaterials and the recent advances in this field. The material science and they are various biological and physical properties affecting their treatment outcome are discussed. Throughout the years, myriads of dental materials have been tried for replacement of missing tooth. Now titanium remains the gold standard as a dental implant material. Over the recent period, many implant biomaterials have evolved. It includes composites, glass-ceramics, metal alloys, ceramics, glasses, and polymers. Nanotechnology is an emerging application in the branch of implant dentistry. Nanotechnology can improve the properties of dental implants for achieving good osseointegration. It is imperative for dental practitioners to have a good idea about the various biomaterials used for dental implants.

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MATERIALS AND METHODS
Titanium and its alloys
Six types of titanium are used as dental implant materials. It includes CpTi and Ti alloys (ASTM). Based on oxygen residuals of metals, the properties of CpTi vary.

There are three structural forms of Titanium alloys which include alpha (α), beta (β) and alpha-beta. The alpha-beta combination alloy is commonly used in dental implants. They are used because of their low density, good strength, and high resistance to corrosion. They also have a low modulus of elas
Table 1: Implant materials can be classified based on the type of material used and the biologic response they elicit when implanted

| Biodynamic activity | Metals | Chemical composition | Polymers |
|---------------------|--------|----------------------|----------|
| Bio-tolerant        | Gold   | Ceramics             | Polyethylene |
|                     | Co-Cr alloys |                                      | Polyamide |
|                     | Stainless steel |                                    | Polymethylmethacrylate |
|                     | Niobium |                                    | Polytetrafluoroethylene |
|                     | Tantalum |                                   | Polyurethane |
| Bio-inert           | Commercially pure titanium | Al oxide |                  |
|                     | Titanium alloy (Ti-6Al-4U) | Zirconium oxide |                |
| Bioactive           |        | Hydroxyapatite       |                  |
|                     |        | Tricalcium phosphate |                |
|                     |        | Bioglass             |                  |
|                     |        | Carbon-silicon       |                  |

Table 2: Ceramic materials are available as dental implants and coatings

| Materials                  | Chemical composition                     |
|----------------------------|------------------------------------------|
| Hydroxylapatite (HA)       | Ca10(P04)6(OH)2                          |
| Tricalcium phosphate (TCP) | α, β, Ca3(P04)2                          |
| Fluorapatite (FA)          | Ca10(P04)6F2                             |
| Tetracalcium phosphate     | Ca4P2O9                                  |
| Calcium pyrophosphate      | Ca4P2O7                                  |
| Brushite                   | CaHPO4, CaHPO4● 2H2O                     |
| Bioglasses                 | SiO2-CaO-Na2O-P2O5-MgO, etc.             |
| Aluminium oxide            | Al2O3                                    |
| Zirconium oxide            | ZrO2                                     |

Titanium Sensitivity associated with Dental Implants

Titanium hypersensitivity can result in several adverse reactions and rapid implant exfoliation (Mitchell et al., 1990; Preez et al., 2007). Review studies suggest that titanium hypersensitivity can lead to implant failure and such events are under-reported (Müller and Valentine-Thon, 2006; Chaturvedi, 2013). In contrast, some studies claim that the role of titanium in causing allergic reactions is unproven (Javed et al., 2013; Siddiqi et al., 2011).

Failure Mode of Titanium

Incidence of fracture of a titanium implant is from 0% to 6% (Balshi, 1996; Tolman and Laney, 1993). Implant fracture is caused by faulty implant design; manufacturing defects; a non-passive fit of the framework or physiological and biomechanical overload (T and U, 1994; Zarb and Schmitt, 1990; Piattelli et al., 1998).

Ceramics

Ceramics as Dental Implant Coatings

Several types of ceramic coatings are used on dental implants (Table 2). It includes bioactive ceramics and inert ceramics. Coatings can be dense or porous with varying thicknesses. There are various methods of coating metal implants (Lacefield, 1998). Bioactive ceramics release calcium phosphate ions around the implants (Groot, 1994; Morris et al., 2000). Plasma-sprayed dense hydroxyapatite and fluorapatite are the most popular calcium phosphate coating materials (Barrère et al., 2003; Guéhennec et al., 2007).

Polymers

Several types of polymers are used as dental implant materials. Due to many disadvantages of polymers like poor mechanical properties, lack of adhesion to...
living tissues, and adverse immunologic reactions, the use of polymers as coatings for implants are not validated nowadays.

**Future trends in implant biomaterials**

**Rapid prototyping or additive manufacturing**

Rapid prototyping or additive manufacturing is a new technology for manufacturing next-generation dental implants. Advantages of this technique include minimal material wastage and printing of multiple objects at a time.

**Application of nanotechnology in dental implants**

With the use of newer technologies, hydroxyapatite (HA) and calcium phosphates (CaP) are coated onto the surface of implants (Knowles et al., 1996). However, there are some controversial and contradictory reports as well, claiming HA coatings as not very beneficial (Wang, 2004). There is an increasing interest to use bio-glass in the fabrication of dental implant coatings. (Hench, 1991) But attempts to coat bioactive glass on metallic surfaces failed due to interaction between metal and glass (Wilson et al., 1993). It is difficult to fabricate an ideal coating with a single technique or material. A combination of techniques and materials are required to manufacture a material with good properties and achieve a thickness in nanometers.

**Biodegradable Implant Materials**

Bio-ceramics are bioimplant prostheses that help to regularize physiological functions. Biomaterials are classified into single crystals, polycrystals, glass, glass-ceramics, polymers and composites. Tissue implant can be bio-toxic, bioinert, bioactive, biore-sorbable/ biodegradable.

**Bio-ceramics**

Currently, bio-ceramics are used for several medical and dental applications (Lin et al., 2003). Bioinert bio-ceramics from zirconia (ZrO2) (Lohbauer et al., 2008) and alumina (Al2O3) (Wittenbrink et al., 2015) was developed initially, followed by bioactive ceramics. Several materials with good biocompatibility like Calcium phosphates (CPs) (Bohner, 2000), hydroxyapatite, dicalcium phosphate dihydrate and tricalcium phosphate are used as bone replacement materials. Bioactive ceramics helps in osteo-conduction due to their inorganic phase (CP). (Groot, 1993).

**Roxolid narrow-diameter implants**

Recently roxolid narrow-diameter implants are introduced from Switzerland. It consists of 83%–87% titanium and 13%–17% zirconium with superior mechanical properties.

**CONCLUSIONS**

Dental implant biomaterials and their design have evolved over the period of time with the advance of biotechnology. With recent advancements, researchers have successfully incorporated artificial structures within biologic systems. Dental practitioners must have a good knowledge of osseointegration properties of different biomaterials used in dental implants for successful clinical practice. A prompt diagnosis and treatment plan is important for selecting a particular dental implant material according to the patients’ needs.

**Conflict of Interest**

The authors declare that they have no conflict of interest for this study.

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**REFERENCES**

Balshi, T. J. 1996. Analysis and management of fractured implants: a clinical report. International Journal of Oral and Maxillofacial Implants, 11(5):660–666.

Barrère, F., van der Valk, C. M., Meijer, G., Dalmeijer, R. A. J., de Groot, K., Layrolle, P. 2003. Osteointegration of biomimetic apatite coating applied onto dense and porous metal implants in femurs of goats. Journal of Biomedical Materials Research Part B: Applied Biomaterials, 67B(1):655–665.

Bidez, M. W., Misch, C. E. 1992. Force transfer in implant dentistry: basic concepts and principles. The Journal of Oral Implantology, 18(3):264–274.

Bohner, M. 2000. Calcium orthophosphates in medicine: From ceramics to calcium phosphate cements. Injury, pages 37–47.

Chaturvedi, T. 2013. Allergy related to dental implant and its clinical significance. Clinical, Cosmetic and Investigational Dentistry, 5:57–57.

Groot, K. D. 1993. Clinical applications of calcium phosphate biomaterials: a review. Ceramics International, 19(5):363–366.

Groot, K. D. 1994. State of the art: hydroxylapatite coatings for dental implants. J Oral Implantol, pages 232–234.

Guéhennec, L. L., Soueidan, A., Layrolle, P., Amouriq, Y. 2007. Surface treatments of titanium dental implants for rapid osseointegration. Dental Materials, 23(7):844–854.

Hench, L. L. 1991. Bioceramics: From Concept to Clinic. Journal of the American Ceramic Society,
Javed, F., Al-Hezaimi, K., Almas, K., Romanos, G. E. 2013. Is Titanium Sensitivity Associated with Allergic Reactions in Patients with Dental Implants? A Systematic Review. *Clinical Implant Dentistry and Related Research*, 15(1):47–52.

Knowles, J. C., Gross, K., Berndt, C. C., Bonfield, W. 1996. Structural changes of thermally sprayed hydroxyapatite investigated by Rietveld analysis. *Biomaterials*, 17(6):639–645.

Lacefield, W. R. 1998. Current Status of Ceramic Coatings for Dental Implants. *Implant Dentistry*, 7(4):315–322.

Lin, S. J., LeGeros, R. Z., Rohanizadeh, R., Mijares, D. Q., LeGeros, J. P. 2003. Biphasic Calcium Phosphate (BCP) Bioceramics: Preparation and Properties. *Key Engineering Materials*, 240-242(3):473–476.

Lohbauer, U., Zipperle, M., Rischka, K., Petschelt, A., Müller, F. A. 2008. Hydroxylation of dental zirconia surfaces: Characterization and bonding potential. *Journal of Biomedical Materials Research Part B: Applied Biomaterials*, 87B(2):461–467.

Mitchell, D. L., Synnott, S. A., Vandercreek, J. A. 1990. Tissue reaction involving an intraoral skin graft and CP titanium abutments: a clinical report. *The International Journal of Oral & Maxillofacial Implants*, 5(1):79–84.

Müller, K., Valentine-Thon, E. 2006. Hypersensitivity to titanium: clinical and laboratory evidence. *Neuro Endocrinology Letters*, 27(1):31–35.

Piattelli, A., Scarano, A., Piattelli, M., Vaia, E., Matarasso, S. 1998. Hollow Implants Retrieved for Fracture: A Light and Scanning Electron Microscope Analysis of 4 Cases. *Journal of Periodontology*, 69(2):185–189.

Preez, L. A. D., Büłow, K. W., Swart, T. J. P. 2007. Implant failure due to titanium hypersensitivity/allergy?–Report of a case. *SADJ: Journal of the South African Dental Association = Tydskrif van Die Suid-Afrikaanse Tandheelkundige Vereniging*, 62(1):24–25.

Siddiqi, A., Payne, A. G. T., Silva, R. K. D., Duncan, W. J. 2011. Titanium allergy: could it affect dental implant integration? *Clinical Oral Implants Research*, 22(7):673–680.

Sykaras, N., Iacopino, A. M., Marker, V. A., Triplett, R. G., Woody, R. D. 2000. Implant materials, designs, and surface topographies: their effect on osseointegration. A literature review. *International Journal of Oral & Maxillofacial Implants*, 15(5):675–690.

T. J., U. L. 1994. Oral implant treatment in posterior partially edentulous. *Implant Dentistry*, 3(3):191–191.

Tolman, D. E., Laney, W. R. 1993. Tissue-integrated prosthetic complications. *Implant Dentistry*, 2(3):202–203.

Wilson, J., Yli-Urpo, A., Happonen, R. P. 1993. Bioactive glasses: clinical applications. *An introduction to bioceramics*, pages 63–73. Springer.

Wittenbrink, I., Hausmann, A., Schickle, K., Lauria, I., Davtalab, R., Foss, M., Keller, A., Fischer, H. 2015. Low-aspect ratio nanopatterns on bioinert alumina influence the response and morphology of osteoblast-like cells. *Biomaterials*, 62:58–65.

Zarb, G.A., Schmitt, A. 1990. The longitudinal clinical effectiveness of osseointegrated dental implants: The Toronto study. Part III: Problems and complications encountered. *The Journal of Prosthetic Dentistry*, 64(2):185–194.