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NANO SURFACE COATINGS & DENTAL IMPLANTS-A REVIEW

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ABSTRACT

Dental Implants have been considered one of the most reliable treatment modality in Dentistry. To enhance clinical performance & Osseointegration of implants, several modifications in topographic characteristics & different surface coatings are tried in which application of nanotechnology therapy has brought a remarkable change. Modifying surface roughness has been shown to enhance Bone to Implant contact (BIC) and improve the clinical performance of implants. Different approaches like application of calcium phosphate (CaP) and Hydroxyapatite coatings using nanotechnology on implants stimulate and enhance osseointegration. The goal of this review is to highlight the role of nanotechnology in implant surface coating modification for improving osseointegration and to enhance its clinical success.

KEYWORDS: Implants; surface coating, nanotechnology

INTRODUCTION

Greatness does not come from size. Surprises come in small packages. "Nano" is derived from the Greek word which stands for "dwarf". Nanotechnology is the science of manipulating matter, measured in the billionths of meters or manometer, roughly the size of two or three atoms.[1] Nanomaterials are those materials with components less than 100 nm in at least one dimension, including clusters of atoms, grains less than 100 nm in size, fibers that are less than 100 nm diameter, films less than 100 nm in thickness, nanoholes, and composites that are a combination of these. Studying dental structures and surfaces from a nanoscale perspective leads to better understanding of the structure function-physiological relationship of dental Implant surfaces. Using nanocharacterization tools, a variety of oral diseases can be understood at the molecular and cellular levels and thereby prevented. Nano-enabled technologies thus provides an alternative and superior approach to assess the onset or progression of diseases, to identify targets for treatment interventions as well as the ability to design more biocompatible, microbe resistant dental materials and implants.[2]

IMPLANT SURFACE DESIGN

Implant surface character is one implant design factor affecting the rate and extent of osseointegration.[3-7] The process of osseointegration is now well described both histologically and at the cellular level. The adhesion of a fibrin blood clot and the population of the implant surface by blood-derived cells and mesenchymal stem cells is orchestrated in a manner that results in osteoid formation and its subsequent mineralization.[8-10] Failures in implant therapy have be attributed to implant design individually, local anatomic and biologic aspects and of course systemic or functional factors. Clinical control, for long term success of implants, with all these factors is a multidisciplinary treatment planning procedure.[11] Implant surface character is one of the design factors which affects the rate and extend of osseointegration both histologically and at cellular level. Adhesion of fibrin clot and blood derived cells along with mesenchymal cells leads to osteoid formation and thus subsequent mineralization.[12] Character of implant surface has been implicated in the process of osseointegration in different ways such as the biocompatible nature of CpTitanium, cellular responses and improvements in bone formation at implant surface.[13] Earlier studies have proven that grit blasted and acid etched surface were capable of rapid and increased bone to implant contact. There has been a number of surface treatments, thus evolved like sand blasting, acid etching, plasma spraying, bio mimetic coating, Anodization etc., Therefore Ti can be modified to enhance bone to implant contact and can influence cellular activity or tissue responses.[14]

BONE IMPLANT INTERFACE

There have been 3 different philosophies, proposed on the improved bone to implant contact which are the Biomechanical theory of Hansson and Norton, Concept of contact osseointegration and surface signalling hypothesis supported by cell culture studies.[15] Hansson described the bone to implant contact, theoretically as well as mathematically, along with the role of surface roughness. According to him; implant surface should be densely covered with pits 1.5µm depth and 3-5 µm diameters. Mechanical interlocking of bone is a necessity for the initial stabilization and signaling of the bone forming tissue.[16] Principal role of fibrin clot stabilization on implant surface is an important factor, along with physical interlocking of fibrin fibers. This promotes the directed on growth of bone forming cells on implant surface. Enhanced surface topography effectively enhances extracellular matrix synthesis and, thus provides faster and reliable osseointegration.[17] Many Micron level topographies are available today, which can improve bone to implant interface which has been supported by earlier clinical studies. Lately, studies on implant surfaces have proven to make osteoinduction of progenitor cells, by immobilization or Nano scale surface engineering.[18] Today, a growing aspect of endosseous implant surface research is focused on further enhancing the activity of bone forming cells at the tissue implant interface. For achieving this type of bioactivity, variety of different approaches have been tried.

NANOTECHNOLOGY AND SURFACE SCIENCE

According National Aeronautics and Space Administration, nanotechnology and surface science is the creation of functional materials, devices and systems through the control of matter on the Nano length meter scale (1-100nm) and exploitation of novel phenomena and properties at that length scale. Nanotechnology involves, both one dimensional concepts involving nano dots and nano wires and self-assembly of more complex structures, nano tubes. Materials can be classified as nano structures, nano crystals, nano coatings, nano particles and nano fibers.[19] Application of nano technology to dental implants involves 2 dimensional association of surface features which are Isotropic, i.e., organized and Anisotropic which defines unorganized dimensional associations. Albretsson and Wennerberg divided implant surface quality into mechanical properties, topographic properties and physicochemical properties.[20] They indicated that these characteristics are related and by changing any of these groups the others will also be affected. One frequently encountered limitation to studies comparing nano- and micron-level surface topography is that it can be extremely difficult to isolate chemistry or charge effects induced by the nanotopography. When atomic level control of material assembly is approached, the surface properties are influenced by quantum phenomena that do not govern traditional bulk material behaviour.[21] The recapitulation of natural cellular environments can be achieved at the nanoscale. Nanoscale modification of an implant surface could contribute to the mimicry of cellular environments to favor the process of rapid bone accrual. Nanotechnology has been shown to influence cell adhesion, proliferation and cell specific adhesion. Related changes in chemistry and nanostructure impart important chemical changes and thereby bio mimetic relationships between alloplastic surfaces and tissues. An important aspect of nano topography that has led to the interest of many investigators is that it is mimics natural cellular environment.[22]

METHODS FOR CREATING NANO FEATURES IN CPTITANIUM IMPLANTS

There are different methods to impart Nanotopography to implant surfaces, some of which are already being used to modify implants available commercially and a number of new techniques are still under trials. Some of these methods are, being discussed. By using a self-assembly monolayer, the exposed functional end group molecule could be one with different function. It could be osteoinductive or cell adhesive molecule. Various physical approaches have also been introduced, like compaction of nanoparticles, which is not very commonly used in dental implants and other is ion beam deposition, where Nano features are imparted to the surfaces based on the type of materials used. Various chemical methods like acid etching, peroxidation, alkali treatment (NaOH) and anodization have also been used to impart Nano topographies by either producing a Titania gel layer or creating an oxide layer. Additive methods of nanoparticle deposition have been used, by using sol –gel, colloidal particle adsorption, where atomic scale interactions display strong physical interaction. Other methods include discrete crystalline deposition and lithography and contact printing technique.

NANO SURFACE TREATMENTS AND CELL INTERACTIONS

Nano topography alters cellular responses, interactions and alters their behavior. It also has specific effects on cellular behavior. They can alter, cell – surface interactions and protein - surface interactions.[23] Protein surface interactions and surface wettability controls osteoblast adhesion and is therefore critical for osseointegration. Protein adsorption mediates subsequent cell attachment and proliferation. Cell binding to protein is mediated by integrin receptors, which are protein receptors that make the cells very social to the new surface.[24]

BACTERIAL ADHESION

Another interesting finding that has been reported in the literature is that bacterial adhesion and proliferation is also diminished on nano phase surface modified materials. Decreased bacterial colonization, with promotion of osteoblast adhesion and differentiation is an ideal approach to implant therapy.[25] Apparently, nanoscale features can increase adherent cell proliferation. In the work by, Webster and his coworkers they reported an increase in the osteoclastic activity and thereby increase in resorption pits.[26]

SURFACE WETTABILITY

Changing the wettability of a biomaterial also alters cell interactions. Extracellular matrix protein adsorption onto surfaces is affected by surface energy that can cause osteoblast adhesion. Cell adsorption and motility are also attributed to the function of integrin's. Anderson and colleagues, said a cell morphology and cytokine production with 15mm wide and 185 nm deep grooves versus substrates with 100nm high and 168nm diameter hemispherical nanopillars, and found cells on hemispherical pillars had smaller areas and more membrane projections and also reduced protein secretion - (70-100nm is considered the best).[27] Zhao and Coworkers used 3 different approaches which are, namely Electrochemical machining, Anodization and chemical etching and they found an inverse relationship between cell proliferation and cell differentiation with diminishing scale of surface roughness.[28] However, Webster and colleagues observed an increased osteoblast proliferation on the nano scale materials tested, thus proving nano surface treatments can improve osseointegration.

SURFACE REACTIVITY AND MINERALIZATION

Nanotechnology is also proven to alter surface reactivity. Existing reports suggest that little bone bonding occurs at endosseous Ti implants, during early phases of bone formation. Bone bonding may be a benefit attributed to Ti implants through nano scale modifications. Initiation of mineralization by absorbed proteins is critical in success of implant therapy. Development of implant bone interface may be influenced by both nano and micron scale parameters. Many different methods are used to impart nano scale surfaces and many are commercially available. In a study conducted in rabbit tibia model higher bone to implant contact was observed for nano scale as compared to micron scale. In studies conducted on canine mandible by means of gap osseointegration, Berglundh and colleagues concluded that healing was greater in Nano scale roughened implant as compared to micron scale.[29] In spite of the above mentioned aspects, the use of nano scale topography and nanotechnology to enhance tissue-abutment interface remains unexplored. However current available evidence proves nano scale surfaces provide incremental advantages to clinical problems when rapid bone to implant surface contact is required.

CONCLUSION

Modifications at nanoscale have been proven to alter the topography and chemistry of implant surface and thus improving the cellular interaction, decreased bacterial adhesion, wettability, increased surface reactivity, mineralization and thus improved osseointegration. Such changes alter the implant surface interaction. Nano scale alterations may provide bone bonding and interfacial bone formation. Long term clinical evaluation will define the potential benefits and risks of manipulating biomaterial interfaces at the nano scale level.

CONFLICT OF INTEREST & SOURCE OF FUNDING

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BIBLIOGRAPHY

1. Kaehler T. Nanotechnology: basic concepts and definitions. Clin Chem 1994;40:1797-9.
2. Kumar PS, Kumar S, Savadi RC, John J. Nanodentistry: A Paradigm Shift-from Fiction to Reality. J Indian Prosthodont Soc 2011;11(1):1-6.
3. Cooper LF. Biologic determinants of bone formation for osseointegration: clues for future clinical improvements. J Prosthet Dent 1998;80:439-49.
4. 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;40:324-35.
5. Boyan BD, Schwartz Z, Hambleton JC. Response of bone and cartilage cells to biomaterials in vivo and in vitro. J Oral Implantol 1993;19:116-22.
6. Schwartz Z, Swain LD, Marshall T, Sela J, Gross U, Amir D, *et al*. Modulation of matrix vesicle enzyme activity and phosphatidylserine content by ceramic implant materials during endosteal bone healing. Calcif Tissue Int 1992;51:429-37.
7. Stanford CM, Johnson GK, Fakhry A, Gratton D, Mellonig JT, Wanger W. Outcomes of a fluoride modified implant one year after loading in the posterior-maxilla when placed with the osteotome surgical technique. Appl Osseointegration Res 2006;5:50-5.
8. Masuda T, Salvi GE, Offenbacher S, Felton DA, Cooper LF. Cell and matrix reactions at titanium implants in surgically prepared rat tibiae. Int J Oral Maxillofac Implants 1997;12:472-85.
9. Meyer U, Joos U, Mythili J, Stamm T, Hohoff A, Fillies T, *et al*. Ultrastructural characterization of the implant/bone interface of immediately loaded dental implants. Biomaterials 2004;25:1959-67.
10. Berglundh T, Abrahamsson I, Lang NP, Lindhe J. De novo alveolar bone formation adjacent to endosseous implants. Clin Oral Implants Res 2003;14:251-62.
11. Adell R, Lekholm U Branemark PI. Problems and complications encountered. J Prosthet Dent 1990;64:185-94.
12. Moore B. Biologic determinants of bone formation for osseointegration clues for future clinical improvements. J Prosthet Dent 1998;80:439-49.
13. Kasemo B. Biocompatibility of Titanium implants surface science aspects. J Prosthet Dent 1983;49:832.
14. Influence of surface characters on bone integration of titanium implants: a histomorphologic study in miniature pigs. J Biomed Mater Res 1991;25:889-902.
15. Hansson S. The relation between surface roughness and interfacial shear strength for bone anchor implants. J Biomech 1999;32:829-36.
16. Albretsson T, Wennerberg A. Oral implant surfaces; part I - review focusing on topographical and chemical properties of different surfaces and in vivo responses to them. Int J Prosthodont 2004;17:536-43.
17. Albert T. Platelet interactions with Titanium modulation of platelet activity by surface topography. Biomaterials 2001;22:2671-82.
18. Evaluation of a predictive model for implant surface topography effects on early osseointegration in the rat tibia model. J Prosthet dent 2001;85:40-6.
19. Christenson EM. Nano biomaterial applications in orthopedics. J Orthop Res 2007;25:11-22.
20. Albrektsson T,Wennerberg A. Oral implant surfaces: part 1 – review focusing on topographic and chemical properties of different surfaces and in vivo responses to them. Int J Prosthodont 2004;17:536-43.
21. Liu H, Slamovich EB, Webster TJ. Increased osteoblast functions among nanophase titania/poly(lactide-co-glycolide) composites of the highest nanometer surface

roughness. J Biomed Mater Res A 2006;78:798-807.
22. Brody S, Anilkumar T, Liliensiek S, Last JA, Murphy CJ, Pandit A. Characterizing nanoscale topography of the aortic heart valve basement membrane for tissue engineering heart valve scaffold design. Tissue Eng 2006;12:413-21.
23. Baraton MI FTIR study of nano structured alumina nitride powder surface, determination of acid/basic sites by CO, CO2 and acetic acid adsorptions. Nanostrumater 1997;8:435.
24. Sinha RK. Regulation of osteoblast integrin expression by orthopedic implant material. Bone 1996;18:451-7.
25. Colon G, Ward BC, Webster TJ. Increased osteoblast and decreased Staphylococcus epidermidis functions on nanophase ZnO and TiO2. J Biomed Mater Res A 2006;78:595-604.
26. Webster TJ, Ergun C, Doremus RH, Siegel RW, Bizios R. Enhanced functions of osteoblasts on nanophase ceramics. Biomaterials 2000;21:1803-10.
27. Andersson AS, Backhed F, von Euler A, Richter-Dahlfors A, Sutherland D, Kasemo B. Nanoscale features influence epithelial cell morphology and cytokine production. Biomaterials 2003;24:3427-36.
28. Zhao G, Zinger O, Schwartz Z, Wieland M, Landolt D, Boyan BD. Osteoblastlike cells are sensitive to submicron-scale surface structure. Clin Oral Implants Res 2006;17:258-64.
29. Berglundh T, Abrahamsson I, Albouy JP, Lindhe J. Bone healing at implants with a fluoride-modified surface: an experimental study in dogs. Clin Oral Implants Res 2007;18:147-52.

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