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# EFFECT OF SURFACE TREATMENTS ON OSSEOINTEGRATION OF DENTAL IMPLANTS

Dentistry

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## ABSTRACT

Osseointegration of dental implants is the most important factor for long term implant success. In the past, the surgical technique was considered to be a major factor influencing implant longevity. Dental implants have macrotopography and microtopography. Recent advances have been made on surface microtopography to enhance osseointegration. Microtopography includes physiochemical, morphogenic and biochemical characteristics, altering these to ensure implant survival for as long as possible in compromised clinical situations. The aim of this article is to elaborate on various surface treatments like plasma spraying, grit blasting, acid etching, laser ablation, anodization, biomimetic agents, nanotubes and others on dental implants for better predictable clinical outcome.

## KEYWORDS

Osseointegration, Microtopography, Surface treatment

## INTRODUCTION-

The main goal of implant dentistry is to achieve good osseointegration for its success. There are many modifications done over past decade to have optimal interaction between the implant surface and surrounding bone.[1] Surface properties like design and implant materials greatly influence the rate and quality of osseointegration. The rapid evolution of dentistry has led to the development of various surface treatments in this area.[2] The objective along with osseointegration, is to shorten the healing period with the use of these modifications. The purpose of this review is to focus on different surface treatment, materials and surface design on dental implant, and their effect on osseointegration.[3]

### Osseointegration-

It is defined as "the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening fibrous connective tissue.[4]" After implant placement, a series of events follows which, leads to its final osseointegration.

### Various phases of wound healing are:

1. **Inflammatory phase-** Non- specific inflammatory cells such as neutrophils are the first cells to reach the site followed by lymphocytes and macrophages which require specific inflammatory response. Platelets attach to the implant surface and clotting process initiates
2. **Proliferative phase-** Neovascularization occurs due to the formation of connective tissue. Fibroblast lay collagen in the bed, strengthening the new granulation tissue.
3. **Maturation phase-** There occurs formation of immature woven bone. This is followed by remodeling and maturation of lamellar bone.[5]

These phases are particularly important in deciding the topography of the implant surface. According to a study conducted by Cooper et al. the implant surface greatly influences the ability of osteoblast to lay down the bone matrix. It was concluded that the implant surface having less optimal treatment responded poorly to osteoblast.[6]

## IMPLANT SURFACE-

Different implant shapes are available hollow or solid, have tapered, parallel or stepped shape and rounded, point or flat apical end. They can be categorized based on surface design as non-threaded or threaded. Primary stability is achieved because of these thread designs and also helps in the dissipation of interfacial forces in the bone.[7] At a more microscopic level, the surface energy and wettability of implant are increased because of a more textured surface topography. Hence, to achieve a better osseointegration surface treatment can be done by various methods.

Plasma spraying and Plasma sprayed Hydroxyapatite coating (HA)- This method is used for roughening the surface of the implant by using titanium plasma spray. At high temperature, the titanium powder is injected into plasma torch. These particles are sprayed on to the surface where they form a layer of 30 µm thick film, it should attain at least 40-50 µm thickness to achieve uniformity. The average surface roughness is around 7 µm which helps to increase the Bone-Implant contact (BIC).[8] The Plasma spraying and Hydroxyapatite (HA) coating is done by the heating of Hydroxyapatite with a plasma flame at a temp of around 15000-20000 K over which HA is forced on the implant surface. It offers more surface roughness and mechanical properties.[9] Early implant loading test also showed significant osseointegration in a vivo animal-based study.[10] Some studies have reported optimization of cell proliferation and scar information.[11,12,13]

### Grit Blasting-

Different types of materials are used like ceramic, alumina, titanium oxide ($TiO_2$) for roughening the surface of implants. Depending upon various sizes of particles used, different surface roughness can be obtained. Alumina is most commonly used as a surface roughening agent. The problem associated with it is blasting material often gets embedded, and the residue remains even after acid passivation, sterilization and ultrasonic cleaning. This may be released after implant placement and could interfere in the osseointegration process.[14] Titanium particles having 25 µm thickness produce roughness of about 1-2 µm range. An in vivo study showed that the use of $TiO_2$ particles led to a significant increase in bone-implant contact than with machined implants.[15] Many studies confirmed that significant changes were noted in osseointegration when $TiO_2$ particles were used.[16,17]

### Acid Etching-

Strong acids are used for the roughening of implant surfaces like HCL, HF, $H_2SO_4$, $HNO_3$. Micropits on implant surface is produced in the range of 0.5 to 2 µm.[18,19] Dual acid technique is followed by the use of HCL and $H_2SO_4$ heated above $100^0$.[20] Osteoconductive process is enhanced by dual acid etching which causes attachment of osteogenic cells resulting in bone deposition on surface of implant.[21] Several studies conducted on dual acid etching showed higher bone-implant contact (BIC) than plasma spraying and machined.[22,23] Another method is with the use of fluoride ions, which leads to the formation of $TiF_4$. Surface roughness was increased, and fluoride incorporation proved to be valuable for osseointegration also, fluoridated rough implants withstood higher torque removal and had greater push out forces as compared to control implants.[24,25] Chemical treatment could reduce the mechanical properties of titanium. Acid etching releases hydrogen which brittles the surface of titanium leading to decrease fatigue resistance.[26]

### Anodization-

The use of high current density (200 $A/m^2$) or potential (100 V) in strong acids like HCL, HF, $H_2SO_4$, $HNO_3$ can cause micro or nanoporosity by anodization. These pores are created by the dissolution of the oxide layer which is initially allowed to be formed on implant surface along the current convection lines.[27-30] The anodization process depends on various factors electrolyte temperature, composition, current density and concentration of acid. Osseointegration has been reported to occur via two mechanism biochemical bonding and mechanical interlocking through bone growth.[31] Incorporation of calcium, phosphorus and sulfur are also indicated. During immediate implant placement, phosphorus-containing anodized surface proved to have a beneficial effect on the early stage of healing. Osseointegration and torque removal values were also increased with calcium ions.[32]

**Machined dental implants (turned surface)-**

Branemark developed these first-generation implants. A scanning electron microscope has to be used for the determination of ridges and grooves which are formed during the manufacturing process. Extensive research have been conducted and reported that these are not preferred especially in poor bone quality.[33]

**Laser ablation-**

These implants are mainly indicated by immediate implant placement in the anterior maxillary region. They have increased corrosion resistance, thick oxide layer and enhanced hardness.[34]

**Sputter Deposition-**

The surface texture of titanium implant can be modified by discharging high energy ions in a vacuum chamber.

**Magnetron sputtering-**

The titanium oxide layer will be formed at bone and implant interface treated with hydroxyapatite (HA). Strong bonding occurs due to diffusion of Ti into the HA layer.[35]

**Biomimetic coating-**

Biomimetic is an "agent/material able to replicate or imitate a body structure (anatomy) and/or function (physiology)."[4]

**Two methods are generally used for biomimetic coatings:**

1. Electrodeposition by passage of current.
2. Immersion in simulated body fluids

**Biomimetic agents-**

Polymers

- Chitosan: A naturally occurring polysaccharide having copolymers of glucosamine and N-acetyl glucosamine. It acts as a scaffold so that the osteoconductive property is enhanced.[36]

Ions

- **Fluoride:**

Bioactive proteins

- Type 1 collagen
- Bone Morphogenic Proteins

Bioceramics

- Hydroxyapatite

**Biologically active drugs:**

**Bisphosphonates-**

Bisphosphonates are anti-resorptive drugs. They inhibit the activity of osteoclasts.[37] Zolendronate a drug used showed improved results in bone-implant contact (BIC) in an animal study.[38] Mechanical fixation was also increased in some patients as per a study conducted by Abtahi et al.[39]

**Simvastatin-**

It is an anticholesterol drug that inhibits the activity of 3-hydroxy-3-methylglutaryl coenzyme reductase, leading to a decrease in cholesterol level. It has been reported that it stimulates the Bone Morphogenic Protein (BMP-2) gene which induces bone formation.[40] Many studies also concluded that simvastatin has excellent potential for osseointegration.[41-44]

**Tetracycline-**

Tetracycline is a broad-spectrum antibiotic which has a dual function by removing the smear layer and killing of microorganism. It can also decrease the collagenase activity and help osteoblastic cell proliferation and bone formation.[45]

**Nanotubes-**

Osseointegration can be increased by these submicron structures. Fibronectin and vitronectin are adhesive particles which are sprayed in nanophase on the implant surface.[46] They are in the range of 15-100 nm. They have added advantage of incorporation of chemicals, drugs and biomolecules in these inner substructures of nanotubes.[47]

## CONCLUSION-

Surface treatment has encouraged osseointegration of dental implants which has led to its use in poor quality of bone, decrease in the healing time and good cellular response for bone formation. Many studies conducted were in-vitro, animal studies and hence need for a more clinical approach is required. The exact mechanism of osseointegration during the initial healing period is still not well understood. Though promising result have been shown the need for further research is of upmost importance.

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