Surface Modification Methods of dental Endosseous implants (Part I)
Surface Modification

- surface coating
- surface treatment
surface coating

- **surface coating**: a *layer of new* material is applied on the implant surface

- **advantage**: wide *range of surface properties* can be obtained, since the film surface may show characteristics that differ substantially from the ones of the coated substrate.

- **Disadvantage**: there is always the possibility of its partial or complete *detachment.*
Surface treatment

- **surface treatment** :- if the surface itself is *changed* by exposing it to physical or chemical agents

- **Advantage**:- allows changing several surface *properties*, such as roughness, morphology and hydrophilicity
  - no risk of *detachment* or delamination, since no material has been added to the surface.

- **Disadvantage** :- the range of effects is more *limited compared* to the case of coating deposition.
Surface Modification Methods of titanium and titanium alloys dental Endosseous implants
• Manufacturing an implant involves turning a long rod of titanium into a cylinder or screw with a resulting surface being referred to as a ‘machined’ surface.

• **Machined titanium surfaces** have ridges and grooves up to about **10 microns deep**.

• The **disadvantage** regarding the morphology of machined implants is the fact that osteoblastic cells are prone to grow along the grooves existing on the surface. This characteristic **requires a longer waiting time between surgery and implant loading**.
Surface treatment

1- Polishing

- **Method** :- using of a fine abrasive material that is applied to a flexible wheel or a belt and then the implant is brought into direct contact with the abrasive surface.

- **Abrasive material** like silicon carbide, alumina or diamond, in presence of lubricant, initially with coarse abrasive followed by a finer abrasive.

- the term ‘**machined surface**’ can be also sometimes used as a description of **polished surface**
2-Grinding

- Grinding involves use of coarse particles as abrasive medium to remove the surface at a faster rate.

- Grinding creates relatively rough surface topographies.
3- Blasting

• By *using* hard ceramic particles delivered through a nozzle at high velocity by means of compressed air.

• Various ceramic particles have been used, *such as* alumina, titanium oxide and calcium phosphate particles.

• The blasting material should be
  o *chemically stable*,
  o *biocompatible* and
  o should not interfere with the *osseointegration* of implants.
• **Alumina** is often embedded into the implant surface and residue remains even after ultrasonic cleaning, acid passivation, and sterilization. In some cases, these particles have been *released into the surrounding* tissues and have *interfered with the osseointegration* of the implants.

• **Calcium phosphates** such as hydroxyapatite, betatricalcium phosphate and mixtures have been used for blasting as they are *resorbable*, leading to a clean, textured, pure titanium surface.

• **Titanium oxide** particles in research studies demonstrated higher bone implant contact, positive success rates and higher marginal bone levels as compared to machined surface.
4- Acid Treatment

- Acid etching of titanium removes the oxide layer and parts of the underlying material.

- The acids commonly used include hydrochloric acid, sulfuric acid, hydrofluoric acid, and nitric acid.

- Each manufacturers have their own acid etching method regarding concentration, time and temperature for treating implant surfaces.
Advantage:

- Lead to uniform roughness improving bioadhesion.

- Yields low surface energy so reduces the possibility of contamination.

- Facilitates retention of osteogenic cells.

- Promoting rapid osseointegration and long term success.
5- Dual acid-etching technique

• This technique employs immersion of titanium implants for several minutes in a mixture of concentrated hydrochloric acid and sulphuric acid heated above 100°C (dual acid-etching) to produce a micro rough surface.

• The dual acid- etched surfaces enhance the osteoconductive process through the attachment of fibrin and osteogenic cells, resulting in bone formation directly on the surface of the implant.
<table>
<thead>
<tr>
<th>Advantage:</th>
<th>Disadvantage:</th>
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<tbody>
<tr>
<td>-higher bone implant contact</td>
<td>-Decrease mechanical properties</td>
</tr>
<tr>
<td>-less bone resorption</td>
<td>-Creating microcracks</td>
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<tr>
<td>-higher adhesion</td>
<td>-Decrease fatigue resistance</td>
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6- Sandblasted large grits-acid etched (SLA) Method

- produced by a large grit 250-500 μm blasting process followed by etching with HCL/H2SO4 mixture at elevated temperatures for 5 minutes or by using 2% HF/10%HNO3.

- Sandblasting results in surface roughness and acid etching leads to cleaning → increase the surface reactivity to the metal. These surfaces have demonstrated improved osseointegration.

Dr. Reem Gamal
7- Alkali Treatment

- Alkali treatment involves immersion of titanium implant in sodium or potassium hydroxide followed by heat treatment and rinsing in distilled water.

- Produce a bioactive, *nanostructured sodium titanate layer* on the implant surface with an *irregular* topography with high degree of *porosity*, forming high bond strength with bone.

- Composition and structure of this layer can be modified by proper heat treatment. Alkali and heat treatment form a bone-like apatite that binds to bone apatite chemically forming high bond strength.
Hydrogen peroxide Treatment

• resulted in chemical dissolution and oxidation of the titanium surface. And formation of \textit{Ti-peroxy} gels.

• The thickness of titania layer formed can be controlled by adjusting the treatment time.

• The thicker layers of titania gel are more favorable for the deposition of apatite.
9- Fluoride Treatment

- treated with fluoride solution.

- Titanium being very reactive to fluoride ions forms *soluble titanium fluoride* which promotes osteoblast differentiation.

- The surface produced has **micro-rough** topography which favors osseointegration.
10- Anodization

- Oxide films are deposited on the surface of the titanium implants by means of an electrochemical reaction.

- Anodization increases the thickness of the TiO$_2$ surface layer (more than 1,000 nm) and also increases roughness making it more biocompatible.

- In this process, titanium surface to be oxidized serves as the anode in an electrochemical cell with diluted solution of acids (sulphuric acid, phosphoric acid, nitric acid etc.) serving as the electrolyte.

- When a potential is applied, ionic transport of charge occurs through the cell and an electrolytic reaction takes place at the anode, resulting in the growth of an oxide film.
• This results in a surface with micropores which demonstrates increased cell attachment and proliferation.

• Two mechanisms have been proposed to explain this osseointegration: Mechanical interlocking through bone growth in pores and biochemical bonding.

• The anodization process is rather complex and depends on various parameters such as current density, concentration of acids, composition and electrolyte temperature.

• The tissue healing process around anodized implants is quicker than in machined implants.
11- Laser treatment

• The process of laser ablation results in titanium surface microstructures with greatly
  ✓ increased hardness,
  ✓ increased corrosion resistance,
  ✓ Produced standard roughness and
  ✓ Produced thicker oxide layer.
ii- Surface coating

1. Sol-gel Method
2. Plasma Spraying
3. Sputtering
4. Biomimetic and bioactive surface coating
1. Sol-gel Method

- The sol-gel method represents a simple and low cost procedure to deposit thin coatings with homogenous chemical composition.

- The coating is fired at 800-900 °C to melt the carrier glass to achieve bonding to the metallic substrate.

- This process is repeated until a relative thick coating (e.g. 100 um) consisting of HA/glass mixture can be obtained.

   **Advantage:**

   - High mechanical strength
   - Accelerate bone formation during initial stages.
2. Plasma Spraying

- **Definition of plasma**
  
  An *ionized gas* consisting of positive ions and free electrons in proportions resulting in electric charge, typically at *low pressures* or at *very high temperatures*.

- This method consists injecting titanium powders into a plasma torch at high temperature. These coatings give implants a *porous surface* that bone can penetrate more readily.
• **Advantage of (TPS):**
  
  • Increasing the **surface area** of the implant
  
  • The **bone/implant interface formed faster** with a TPS surface than with smooth surface implant

• **Disadvantages of (TPS):**

• Metallic **wear** of titanium **particles** from implant found in the adjacent bone, liver and spleen. which may cause macrophages aggregations leading to local and systematic carcinogenic effect.
3. **Sputtering**

- **Sputtering** is a process where atoms or molecules of a material are ejected in a vacuum chamber by bombardment of high-energy ions.

- **common drawback:**
  - the deposition rate is very low
  - the process itself is very slow.
• The coating shows **strong adhesion** to the titanium, improve bone strength and initial osseointegration rate.

• **A-Radio frequency sputtering (RF)**:
  - largely used to deposit thin films of CaP coatings on titanium implants.

• **B-Magnetron sputtering**:
  - thin-film technique as it allows the mechanical properties of titanium to be preserved while maintaining the bioactivity of the coated HA.
<table>
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<tr>
<th><strong>Advantage of HA coating:</strong></th>
<th><strong>Disadvantages of HA coating:</strong></th>
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<tbody>
<tr>
<td>• No cellular toxicity</td>
<td>• May crack upon insertion especially in dense bone</td>
</tr>
<tr>
<td>• Increase osseointegration in cases of poor bone quality</td>
<td>• Increase surface roughness cause increase bacterial contamination</td>
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<tr>
<td>• Increase initial stability in case of immediate loading.</td>
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• Research developments directed towards improved and faster osseointegration have shown that implant surface properties can also be modified by incorporating bioactive factors or biomimetic agents into the implant surface.
• These include
  • cell-adhesion molecules like fibronectin, vitronectin, type I collagen, osteogenin and bone sialoprotein;
  • several growth and differentiation factors such as transforming growth factor (TGF), platelet derived growth factor (PDGF), insulin-like growth factor (IGF), bone morphogenetic proteins (BMPs), which may act as bone stimulating agents
  • incorporation of bone antiresorptive drugs such as bisphosphonates, statins like simvastatin,
  • antibacterial coatings including gentamycin or tetracycline have demonstrated impressive potential for improving the nature of osseointegration.
Thank you