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Different surface topography of dental implant

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Abstract

In order to achieve the osseointegration, the surface of endosseous is considered as one factor determining the formation of bone-implant interface. Commercially pure (Cp) titanium implant has been widely to restore the missing teeth, however, nowadays there are many different surface treated implants in dentistry. They have shown the various clinical success and failure rates. Although the high success rate of using Cp machined titanium implant is well documented, the rough surface implant has also been shown to have a crucial role on the osseointegration. Rough surface can be created by coating with hydroxyapatite, titanium or by removing titanium surface with sandblasting or acid-etching. There are many studies shown that rough surface not only accelerates bone-implant formation but also increases removal torque. However, more clinical studies are required to prove theses benefits. (CU Dent J 2001;24:51-6)

Key words: osseointegration; surface treated implant

Introduction

Since 1960s, endosseous implants have been used in human, there are many evidence to show the high successful clinical employment of implant.[1-5] However, the successful implants not only establish osseointegration but also have to maintain the achieved osseointegration. There are many dental implant companies in the market to provide the varieties of implant systems to satisfy the practitioners' needs. There is also a lot of extrapolation between different implant systems. However, it is not possible to say that one implant will provide the same results as another one just because it looks the same. Moreover, when it comes to serve the increasing needs of implant dentistry, the shorter procedure or time will play an even increasing role. From the conventional two-stage procedure (submerged implantation) to one-stage procedure (nonsubmerged implantation), the one-step procedure has been proved successfully.[1,6,7] To shorten the healing time, osseointegration has to be achieved as soon as possible. Although Commercially pure (Cp) titanium has been demonstrated to be a material with very good biocompatibility, the characteristics of rough surfaced implant have shown to have influence on bone integration of titanium implants.[8,9] The main objective of different surface treatment is to rough surface to improve osseointegration. Thus, the researchers have been developing the different surface treatment on implant to accelerate the osseointegration to meet the practitioners's needs. This article is, therefore, to review the different surface topography of dental implants and their surface characteristics.

Review of the literatures

Machined surface

Of the many different metals used in implantology, titanium has been shown to be very good biocompatibility. Titanium is used either as the pure titanium (99.75%) or as titanium alloy (T6A14V). Titanium is non-noble

metal, protected by a passivated layer of titanium dioxide that forms spontaneously in air as well as in water. According to the Branemark's concept on "osseointegration", it should be direct contact between viable bone and implant surface without inter-posing soft tissue layer. However, many histological studies have shown that there is attachment between the implant surface oxide layer and the adjacent epithelium. Hemidesmosomal like structure were observed along the epithelial cell membrane adjacent to implant surface. This attachment is mediated by glycoprotien similar to that seen between epithelium and natural teeth.[10-14] However, the precise biological mechanism of bone-implant interface is still not clear. Even though there will be average vertical bone loss about 0.2 mm annually after the first year of service according to criteria by Smith and Zarb in 1989[15], Belser and Wiskott (1999)[16] recently claimed that there is no integration between bone and titanium surface. They argued that the smooth surfaces will not provide adequate biomechanical coupling with the bone surrounding the implant surface as the stress range induced by a polished surface is limited. They also explained that instead the surface texture of threaded, coated or sandblasted implants generates a heterogeneous stress field around an implant in function to induce osteocytes to form new bone. However, Cp Titanium implant has been used successfully to restore the missing teeth as it can be seen from the previous studies.[2-4]

Titanium Plasma-Sprayed (TPS) surface

Plasma-Sprayed coating used to create a rough surface was first introduced by Hahn and Palich in 1970.[17] It has been believed that the percentage of bone-implant contact necessary to create sufficient anchorage to permit successful implant function as a load-bearing device over time. There are some Titanium Plasma-Sprayed implant system in the market such as ITI, IMZ etc. This method is to use special plasma spraying technique, as it involves forcing noble gas (Argon), Which is split into ions and electrons (plasma), through an intensely burning (15,000-20,000 °C) arc at very high speed (3,000 m/s). Ti powder (size about 50-100 μm) is introduced in an argon gas stream at the tip of the flame and is accelerated to approximately 600 m/s as drops of molten metal to weld to the implant surface 15-20 cm away. The resulting surface layer has a thickness of about 0.03-0.05 mm and shows a roughness depth profile of about 15 μm. Experimental studies in animals comparing between polished surface implant by electropolishing and rough surface implants (without electropolishing) showed significantly higher removal torque for rough-surfaced implant than smooth-surfaced implants and rough surfaced implants also demonstrated an increase in bone apposition compared to polished surfaced implants.[8,18] It is suggested that soft tissue components attach better to smooth-polished surfaces but the rough surface is more conducive to bone attachment.[19] This finding has supported the previous study on Titanium Plasma-Spraying by Sutter et al. (1988) which showed that TPS implant has optimal micromorphological structure for formation of direct bonding between bone and implant surface.[20] The International Team of Oral Implantology (ITI®) had successfully used implants with TPS surface treatment and it revealed that non-submerged ITI implant could achieve the success rates above 90% for observation period up to 8 years.[1]

Sandblasted surface

Instead of changing from the smooth implant surface to the rough surface by adding material, it can be done by removing material from the smooth surface for example sandblasting, or acid-etching treatment. The advantages of these techniques are that there is no contamination, and they also increase surface area and mechanical interlocking. Wennerberg *et al.* (1998) used custom "split" implants in animals with one side being a machined surface and the other side blasted with three sizes (25, 75, 250 μm) of aluminum oxide (Al_2O_3) particles. They found that blasted surface demonstrated more bone contact to the implant surface than the smooth surface implant. Moreover, histomorphometric analysis showed surface implant blasted with 75 μm Al_2O_3 particles demonstrated greater bone-implant contact than machined surface or ones blasted with 25 or 250 μm Al_2O_3 particle.[21]

Acid-etched surface.

Apart from sandblasting technique, acid etching is another way to create rough surface. Usually, the acid used to attack implant surface is HCL/H_2SO_4. Recently, ITI® has introduced another surface treated implant "SLA™" (Sand-blasted, Large grit, Acid-etched) into the market. The SLA surface has a characteristic of double roughness. The macro roughness is achieved by the large-grit sand-blasting and the micro roughness is created by acid etching. The company also claimed that the prosthetic restoration can be started within 6 weeks after the implants placement in the patients with

adequate bone. This means that it is going to shorten healing for the patient by initial speed of integration. We still need long-term study to improve the benefit of this surface treatment. Although one experimental study showed that SLA implants had a significantly higher bone-implant contact than TPS or sandblasted implants. Probably the acid not only attacked the titanium surface creating secondary roughness, but also removed the remaining grit particles of aluminum oxide embedded in the titanium surface.[8] Apart from TPS surface implant, 3i implant innovation® has introduced acid-etched surface implant, "Osseotite". The machine implant surface is subjected to acid-etching with HCL/H_2SO_4. The advantages of acid-etched surfaced implant are free contaminants, surface area compared to machined surface, and no coating compared to HA-coated or TPS-coated implants. Recently, one-year human experimental study[22] showed that the acid-etched surface (Osseotite) implant achieved earlier and higher bone to implant surface than did the machined surface implants. This in turn allowed the practitioners to start prosthetic works earlier (Early loading) instead of waiting for 3-6 months as conventional implant protocols. This study showed the high cumulative survival rates of osseotite of 98.5% at 12.6 months. However, it was 1 year study so more long-term study may be required on this protocol.

Hydroxyapatite coated surface

The most common ceramic used to coat the implant surface is hydroxyapatite (HA). It has been postulated that hydroxyapatite would lead to accelerated osseous healing as well as overall improvement of the interface area between bone and implant. There are controversial studies on this type of surface treated implant. The coatings contain both amorphous glassy and crytalline components and can be dense or porous. A dense coating is supposedly higher in strength and lower in solubility. It is recommended that the coating have even thickness 50-100 μm and not obliterate surface geometry. The tensile strength of the coating to the metal is reported to be 40-80 MPa and shear strength is 10-20 MPa. Due to characteristic of ceramic material, the brittle nature is an undesirable property so it will be difficult to fabricate the thick section and to control the even thickness.[23] HA-coated implants have found that there was higher percentage of direct bone contact compared with uncoated cp titanium implants, titanium-coated implants or SLA implants.[8,23,24] HA is one of the most biocompatible material. It has been shown to improve the rate and strength of initial osseointegration. HA-coated implant demonstrates osseoconductive property with formation of new bone contact. However, it was found that there was sign of resorption of HA-coated implant[8] which was contrast to a study by Block *et al.*[25] Study by Block *et al.* disputed previous studies and showed that the HA-coating did not show significant resorption after 9-year placement. Another retrospective study by Wheeler has shown that even though HA-coated implants had higher initial survival rate than TPS implants, after 4 year the HA-coated implant survival rates became significantly lower than TPS implants. HA-coated implants had cumulative survival rate of only 77.8% after 8 years compared to 92.7% of TPS implants. He claimed that the long-term prognosis of HA-coated implants was probably due to one of the problem of inflammatory breakdown around implants.[26] However, the difference in the pattern of bone contact between HA-coated implant cp Titanium has been investigated yet. One postmortem histologic study by Rohrer *et al.*[27] revealed that even though the percentage of the bone contact was higher on the mandible cp Titanium implants, compared to HA-coated implants in maxilla (56.4% VS 47%), bone contact was more uniform and solid on the maxillary HA-coated implants, similar to the study by Block *et al.*[25] They claimed that there was much more marrow in the mandible with cp Titanium implants than in maxilla with HA-coated implants. However, this investigation was done in one patient and also compared between mandible and maxilla which have different bone characteristic but it has shown some interesting finding which encourages the researchers to study more before drawing a conclusion.

Discussion

The surface topography is one of the properties which are proved to have an influence on the osseointegration. Although the smooth surface of dental implant has been generally accepted, it is not successful in every quality and quantity of bone. Thus, developing surface topography is necessary to improve the property of dental implant and to increase the success rate in implant dentistry. A few *in vitro* and *in vivo* studies have indicated that soft tissues interact better with smooth polished titanium surfaces, whereas rough titanium surfaces tend to promote bone tissue formation and osseointegration.[8,19,28,29] It can be seen that the interface reactions between metallic implants and the various

surrounding tissues play an important role in the success of dental implant. There are many techniques to create the rough surface of dental implant as previous mention. By using SEM, polished surface titanium implant has roughness about 81 nm, whereas the sandblasted and acid-etched surface showed higher degree of roughness. Acid-etched surface showd roughness around 2100 nm and sandblasted/acid-etched surface showed roughness 3600 nm. Moreover, when investigating on the chemical composition and the wettability properties of titanium surface, it was seen that the surface treatments (acid-etched, sandblast or plasma-spray) still preserved the properties of titanium native oxide layer compared to polished surface titanium.[30] However, the practitioners should consider the properties of each dental implant systems that have been treated with different techniques. Even though the HA-coated implant had shown the high rate of early bone-implant formation[23,26], it has also been shown that they might be related to peri-implantitis.[31,32] Whereas to shorten the healing period time, the rough surface dental implant has been used as we can seen in many studies on early or immediate implantation.[22,33,34] However, they are only short-term studies. Thus, before definitive conclusion can be drawn about superiority of these development, more long-term clinical studies are required.

Conclusion

Although the long-term clinical success of Cp titanium is well documented, the importance of surface characteristic and topography cannot be underestimated and further researches should be carried on to increase the success rate in implant dentistry.

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ลักษณะพื้นผิวที่แตกต่างกันของรากเทียม

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บทคัดย่อ

ลักษณะพื้นผิวของรากเทียมเป็นหนึ่งในหลายปัจจัยที่จะช่วยส่งเสริมให้เกิดการเกาะติดระหว่างผิวของรากเทียมกับกระดูก ถึงแม้ว่ารากเทียมที่ทำขึ้นจากโลหะไททาเนียมบริสุทธิ์ทางการค้าจะถูกนำมาใช้ในการบูรณะ และชดเชยฟันที่สูญหายไปมาช้านานแล้วก็ตาม รวมทั้งได้แสดงให้ถึงอัตราความสำเร็จที่สูง แต่ปัจจุบันจะพบว่ารากเทียมได้ถูกพัฒนาให้มีลักษณะพื้นผิวที่แตกต่างกันออกไปเพื่อสนองความต้องการของทันตแพทย์ ซึ่งนอกเหนือจากรากเทียมไททาเนียมที่มีผิวเรียบที่ถูกยอมรับอย่างกว้างขวางแล้ว รากเทียมที่มีผิวหยาบได้ถูกนำมาทดลองและใช้ รวมถึงแสดงให้เห็นถึงผลของลักษณะของพื้นผิวรากเทียมต่อการเกาะติดระหว่างผิวของรากเทียมกับกระดูก รากเทียมสามารถถูกทำให้เกิดผิวที่หยาบได้โดยการเคลือบด้วยไฮดรอกซีแอปพาไทต์ หรือ ผงไททาเทียม หรือโดยการกัดผิวรากเทียมด้วยทรายละเอียด หรือใช้กรดกัด ซึ่งจากหลาย ๆ การศึกษาได้แสดงให้เห็นว่ารากเทียมที่มีผิวหยาบนอกเหนือจากจะเพิ่มอัตราการเกาะติดระหว่างผิวของรากเทียมกับกระดูกแล้วยังเพิ่มแรงต้านแรงบิดหมุนในห้องปฏิบัติการ อย่างไรก็ตามยังต้องมีการศึกษาเพิ่มเติมทางคลินิกอีกมากก่อนที่จะสรุปถึงข้อดีต่าง ๆ ของรากเทียมที่มีผิวหยาบ

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