人工牙根植體邊界狀態及骨癒合之自然頻率分析

Natural frequency assessment of boundary conditions and osseointegration for dental implants

中文摘要

過去雖有不少關於人工植體穩固度的研究，但到目前爲止，仍沒有一項簡單的設備或方法來評估人工植體植入後骨邊界變化的情形，且可持續地追蹤其固持狀態。又自然頻率爲物質剛性與質量的函數，可用來檢測結構的邊界條件變化，因此本研究即爲利用自然頻率模態測試法，從體外及體內實驗，分析自然頻率於人工植牙骨癒合過程及邊界變化的效應。由體外模擬實驗結果可發現，植體之自然頻率值會隨邊界物質剛硬性的增加而上升，而隨植床情況的不同，其自然頻率值上升曲線會有差異（$p<0.05$），並分別在不同時間達到穩定高原期。另外由移除扭力測試時可知，植體移除扭力值與自然頻率值均在相同的時間點呈現出穩定的趨勢，但相較於自然頻率測試法，移除扭力並無法有效偵測在此邊界穩定時間點前邊界狀態的變化。而研究結果亦發現移除扭力值與自然頻率值雖存有相關性（$p< 0.05$），但其完全之正相關只有 25.32 %（R2=0.2532）。在動物體內，隨骨整合的進行，植體自然頻率值每週約有 227~334 Hz 的上升量，而隨個體及手術狀況的不同，如同體外實驗，植體自然頻率值亦分別在不同時間達到高原期；另在骨整合失敗的情況中，植體自然頻率值在第一週會有約 12%的下降。此外，在體外邊界狀況改變的實驗中發現，植體自然頻率會受到邊界物質高度、厚度以及密度的影響；在邊界高度變化的檢測上可見，當邊界密度越低且厚度越厚時，以自然頻率測試邊界高度下降的鑑別度越高；而隨邊界密度的不同，植體自然頻率亦有不同的差異（$p<0.05$）。由以上結果可知，自然頻率可有效偵測植體邊界穩固度變化的情形，乃爲一值得努力發展的方向。

英文摘要

Although there were numerous studies published on the stability of dental implant during osseointegration, but up to now there is still a strong demand for a simple device to be used to evaluate the boundary conditions during bone healing. Natural frequency is a function of the mass and stiffness of a material. Such concept has been used to detect changes in boundary conditions of a structure. Thus current study was based on the methodology of modal testing, from both in vitro and in vivo, analyze the processes of osseointegration and variation in boundary condition. From our in vitro study, it was found that natural frequency of test implant increased with stiffness of boundary material. With different implant bed conditions, the slope of the healing curve would show corresponding changes. On the other hand, natural frequency and removal torque value reached the plateau at the same time. However, before the

plateau phase, method only natural frequency will be able to detect changes in boundary conditions, but not with removal torque method. Although we found linear correlation between natural frequency and removal torque values, but the correlation coefficient was only 25.3 %. In the in vivo condition, along with the process of osseointegration the increase in natural frequency of a implant was about 227 Hz ~ 334 Hz per week. The final healing time was affected by individual differences, and operation conditions. Also, when the surgery was not successful, natural frequency showed 12% reduction during the first week of healing. In the in vitro experiment, our results showed a positive correlation between natural frequency and boundary heights, boundary width, and boundary density. It was found that as boundary density decreased, boundary width increased, natural frequency method would show highest sensitivity in detection of changes in boundary height. Also, along with changes in boundary density, the natural frequency would show significant changes ($p<0.05$). Thus, it is concluded that natural frequency is an effective method to detect variation in boundary condition during osseointegration of an implant.