內建壓電陶瓷感測元件之機構化牙科植體穩固度檢測裝置設計與驗證

New design and verification of the motor-driven stability detecting device with built-in piezoelectric ceramic sensing element for dental implants

中文摘要

在口腔醫學臨床診斷利用共振頻率來檢測牙科植體與齒槽骨間之癒合程度，係取其非侵入性與非破壞性的優點，近年來成趨勢，然其再現性與精確性仍未盡完善。因此本研究利用共振聲頻檢測技術開發新型牙科植體穩固度檢測裝置，配合臨床使用上安全性及安裝便利性之要求，設計一小型檢測裝置能完全置入口中並能由口外進行遙控操作，並以壓電陶瓷片裝備於機構化的衝擊錘尾端為設計主軸，使得衝擊瞬間能產生激振訊號，而以此訊號觸發(Trigger)系統執行量測，並即時(Real time)利用麥克風將牙科植體被激發之振動訊號傳回頻譜分析儀進行訊號處理，再利用快速傅立葉(FFT)轉換程式分析振動反應與判讀，找出牙科植體系統的反應頻譜與共振頻率。先利用自製壓電陶瓷衝擊錘對模態測試專用敲擊錘進行衝擊，兩者所得數據以迴歸法分析並作為校正依據，其 r2 為 0.9848 ($p<0.005$)，具明顯相關性，驗證自製壓電陶瓷衝擊錘之量測精確性、再現性與動態響應皆能符合模態測試技術之要求。繼而設計植體骨癒合與外露高度之離體模擬實驗進一步驗證此一新型檢測裝置能否有效偵測牙科植體與齒槽骨固持狀態之共振頻率，並以本研究室過去一系列傳統模態測試法進行比較驗證。利用虎鉗挾持牙科植體進行量測，以模擬植入後之穩固度變化，當挾持扭矩由 2 kgf-cm 至 10 kgf-cm 增量變化時，新型檢測裝置與傳統模態測試之共振頻率量測結果有逐步升高現象。植入後外露高度分別設定為 7 mm 至 11 mm，新型檢測裝置與傳統模態測試之共振頻率量測結果有逐步降低趨勢。新型檢測裝置與傳統模態測試兩者所得數據以迴歸法分析，其 r2 為 0.9632 ($p<0.005$)，證實其確能與傳統模態測試一樣，成功地辨識在不同植體骨癒合與外露高度模擬條件下的共振頻率值，亦即本研究之設計能夠有效追蹤判讀其穩固程度變化。而傳統模態測試之標準差分布為 70.0 ± 89.8 Hz、全距為 466.1 Hz；新型檢測裝置之標準差分布為 43.4 ± 24.8 Hz、全距為 95.3 Hz；更可看出新型檢測裝置之標準差分布與全距均比傳統模態測試小。依此先期離體實驗證明新型檢測裝置能成功辨識在不同骨癒合模擬條件下的共振頻率值並有效追蹤判斷其穩固程度變化，且新型檢測裝置比傳統模態測試法能更精確與敏銳的測得共振頻率值，進而更精準的間接判斷骨癒合狀態，成為人工植牙手術最佳之臨床輔助診斷工具。

英文摘要

In recent years, more and more researchers have used the resonance frequency technique to detect the stability of dental implant. The advantage of this technique is non-invasive and non-destructive; however, its repeatability and accuracy are not satisfied. This thesis presents a new clinical technology to detect the stability of dental implant precisely by using resonant acoustic method. Besides, a compact dental implant stability detector equipped with piezoelectric ceramic and non-contact acoustic receivers are also developed. The basic idea is, firstly, to retract the impact force signal by using the piezoelectric ceramic and the vibration resonance signal by using non-contact acoustic receivers. Then, the force signal can trigger a frequency spectrum analyzer to acquire the data of impact force signal and response acoustic signal simultaneously. The Fast Fourier transform (FFT) method is then applied to convert the both signals from time domain to frequency domain and calculate the frequency response function (FRF). The FRF can provide the dental implant on the tooth bone boundary clinical inspection information. In order to verify the practicability of the proposed devices, two experiments are conduced for verification. The piezoelectric ceramic function should be checked and calibrated firstly by using the commercial PCB GK291C80 impact hammer and then, both the responsive signals are collected. The r2 of regression result is 0.9848 ($p<0.005$). It represents the measurement accuracy and its good repeatability. In addition, the dynamic response of home-made piezoelectric ceramic hammer matches well with the expected resonant acoustic test criteria. As for the stability test, when the dental implant is clamped by vise with force increasing from the ranges of 2 to 10 kgf-cm, the measured data are increased. The dental implant is fixed in the PE rod with the outside length increasing from 7 mm to 11 mm and the measured data are decreased. The r2 of regression result is 0.9632 ($p<0.005$) when the traditional impulse force resonance method is taken as the control group. The standard deviation of control group measured data is 70.0 ± 89.8 Hz with a frequency span of 466.1 Hz. In contrast, the standard deviation of the current study is 43.3 ± 24.8 Hz with a frequency range of 95.3 Hz. From the testing results, it implies that this newly developed device can detect the osseointegration condition of dental implant on the tooth bone boundary more effectively and its stability and sensitivity are also better than those of the conventional device.