科技部補助專題研究計畫成果報告
期末報告

探討多切面電腦斷層掃描於牙科醫學造影之影像品質與輻射劑量最適化研究：由64切至320切

計 畫 類 別 ： 個別型計畫
計 畫 編 號 ： MOST 103-2314-B-040-023-
執 行 期 間 ： 103年12月01日至104年12月31日
執 行 單 位 ： 中山醫學大學醫學影像暨放射科學系(所)

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大專生-兼任助理人員：余志薇
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中 華 民 國 105 年 02 月 21 日

中 文 摘 要 ： 目的：本研究將提供可適用的掃描參數於320切電腦斷層(320-slice multi-detector computed tomography, 320-MDCT)造影上，以提升診斷牙科檢查影像品質並可降低輻射劑量。
方法：本研究使用擬人頭部假體做為標準，掃描320-MDCT不同的掃描參數，包含體積/螺旋式掃描與12組不同管電壓/管電流變化。在三個平面影像(矢狀面、冠狀面、軸向面)上，評估6處骨頭組織與3處軟組織作為定量與定性分析比較。使用Figure-of-merit (FOM)結果決定最佳化的影像掃描參數。
結果：在定量與定性分析上，80 kVp相較135 kVp或120 kVp，在骨頭組織與軟組織部位皆得到最差的結果，且具有顯著意義(P<0.001)。在定量分析上，120 mA較60 mA明顯優異，但在定性上並無發現。相較螺旋式掃描，使用體積式掃描可得到較高的FOM值。
結論：在320-MDCT中，使用135 kVp/80mA搭配體積式掃描模組，可實質的提供軟組織與骨頭組織影像評估，同時可使得輻射劑量在抑低合理範圍內，因此認為此參數可作為牙科的造影選擇。

中 文 關 鍵 詞 ： 牙科電腦斷層、影像品質、輻射劑量

英 文 摘 要 ： Objective: To propose a feasible protocol that provides satisfactory image quality for diagnosis on the oral examination while minimizing radiation dose in 320-slice multi-detector computed tomography (320-MDCT).
Methods: Anthropomorphic head phantom was scanned using a 320-MDCT with protocols combined different scanning modes (Volume scan (whole or local) or helical scan (80 or 64 slice detectors) and 12 different tube voltage and tube current. 6 anatomical bone structures and 3 anatomical soft-tissue structures were assessed by quantitative and qualitative analysis in the three orthographic planes (axial, sagittal and coronal). The figure-of-merit (FOM) was used to determine the optimized imaging protocol, in terms of tube voltage, tube current and scanned modes.
Results: The setting of 80 kVp was shown to have worst quantitative and qualitative (both P <0.001) result as compared with 135 kVp and 120 kVp at bone and soft-tissue structures. Significant difference was noted for the scores obtained at tube current between 120 mA and 60 mA by quantitative analysis, but not by qualitative analysis. Volume scans from whole or local modes have the significantly higher FOM than from 80 and 64 slices modes.
Conclusion: In 320-MDCT, the protocol using 135 kVp, 80 mA, and volume scan mode (whole or local) has offered adequate visualization for both soft-tissue and bone structures while keeping the radiation dose as low as achievable, which may be considered as one of the first choices among a wide selection of scanning protocols when dealing with dentomaxillofacial CT.

英文關鍵詞： dentomaxillofacial CT, Image quality, Radiation dose

科技部補助專題研究計畫成果報告

（□期中進度報告/■期末報告）

探討多切面電腦斷層掃描於牙科醫學造影之影像品質與輻射劑量最適化研究：由 64 切至 320 切

計畫類別：■個別型計畫　□整合型計畫
計畫編號：MOST 103-2314-B-040-023
執行期間：　2014 年 12 月 1 日至 2015 年 12 月 31 日

執行機構及系所：中山醫學大學 醫學影像暨放射科學系

計畫主持人：蔡佳容
共同主持人：林緯展
計畫參與人員：陳奕倫、余志薇、楊恒宜、李振銓

本計畫除繳交成果報告外，另含下列出國報告，共 ___ 份：
□執行國際合作與移地研究心得報告
□出席國際學術會議心得報告

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中　華　民　國　105 年　2 月　17 日

目錄

中文摘要

目的：本研究將提供可適用的掃描參數於 320 切電腦斷層(320-slice multi-detector computed tomography, 320-MDCT)造影上，以提升診斷牙科檢查影像品質並可降低輻射劑量。

方法：本研究使用擬人頭部假體做為標準，掃描 320-MDCT 不同的掃描參數，包含體積/螺旋式掃描與 12 組不同管電壓/管電流變化。在三個平面影像(矢狀面、冠狀面、軸向面)上，評估 6 處骨頭組織與 3 處軟組織作為定量與定性分析比較。使用 Figure-of-merit (FOM)結果決定最佳化的影像掃描參數。

結果：在定量與定性分析上，80 kVp 相較 135 kVp 或 120 kVp，在骨頭組織與軟組織部位皆得到最差的結果，且具有顯著意義(P<0.001)。在定量分析上，120 mA 較 60 mA 明顯優異，但在定性上並無發現。相較螺旋式掃描，使用體積式掃描可得到較高的 FOM 值。

結論：在 320-MDCT 中，使用 135 kVp/80mA 搭配體積式掃描模組，可實質的提供軟組織與骨頭組織影像評估，同時可使得輻射劑量在抑低合理範圍內，因此認為此參數可作為牙科的造影選擇。

關鍵詞: 牙科電腦斷層、影像品質、輻射劑量

Abstract

Objective: To propose a feasible protocol that provides satisfactory image quality for diagnosis on the oral examination while minimizing radiation dose in 320-slice multi-detector computed tomography (320-MDCT).

Methods: Anthropomorphic head phantom was scanned using a 320-MDCT with protocols combined different scanning modes (Volume scan (whole or local) or helical scan (80 or 64 slice detectors) and 12 different tube voltage and tube current. 6 anatomical bone structures and 3 anatomical soft-tissue structures were assessed by quantitative and qualitative analysis in the three orthographic planes (axial, sagittal and coronal). The figure-of-merit (FOM) was used to determine the optimized imaging protocol, in terms of tube voltage, tube current and scanned modes.

Results: The setting of 80 kVp was shown to have worst quantitative and qualitative (both $P < 0.001$) result as compared with 135 kVp and 120 kVp at bone and soft-tissue structures. Significant difference was noted for the scores obtained at tube current between 120 mA and 60 mA by quantitative analysis, but not by qualitative analysis. Volume scans from whole or local modes have the significantly higher FOM than from 80 and 64 slices modes.

Conclusion: In 320-MDCT, the protocol using 135 kVp, 80 mA, and volume scan mode (whole or local) has offered adequate visualization for both soft-tissue and bone structures while keeping the radiation dose as low as achievable, which may be considered as one of the first choices among a wide selection of scanning protocols when dealing with dentomaxillofacial CT.

Keywords: dentomaxillofacial CT, Image quality, Radiation dose

Introduction

Three-dimensional imaging have started to play an important role in oral diagnosis for screening purposes, periodontal evaluation, orthodontic treatment planning, oral surgery, and in implant treatment planning as well. This is especially the case for cone-beam computed tomography (CBCT) or multi-detector computed tomography (MDCT). There is some evidence proves that the panoramic images generated by CT offered equal image interpretation to conventional digital panoramic radiographs [1-3]. For CBCT, some researches offered recommendation of exposure parameters for different examinations that achieve substantial dose reduction with minimal loss of diagnostic information [4, 5]. The potential of low-dose protocol for CBCT has further been evaluated in a clinical series for its use in dental implant site [6]. Both MDCT and CBCT have its own shortcomings, MDCT provided much fewer artifacts in comparison with CBCT. Some studies showed images of the implant can be correctly reproduced by means of MDCT in all the axial and coronal cross-sections as compared with CBCT. However, CBCT could not be replaced by MDCT so far, because of the relatively higher radiation dose delivered by MDCT [7].

The recently introduced 320-slice MDCT scanner has equipped a detector row length of 16 cm which enables an overall coverage of the whole maxillofacial region within a 0.5-second rotation time. The scanning time of 320 MDCT is much faster as compared to the CBCT with a rotation time of 10-70 seconds, and has thus resulted in significant potential of dose reduction. As for dose reduction, there are important parameters such as tube voltage and tube current also greatly influence the resulting radiation exposure, which should be taken into account when adhering to the as low as reasonably achievable (ALARA) principle [8]. We have noticed that the study exploring the optimized protocol design in terms of selection of tube voltage, tube current settings in 320-slice MDCT for dental imaging has not been reported earlier. Furthermore, in order to design an optimized scanning setting, a balance between diagnostic image quality and radiation dose should be accomplished without much trade off of each other, particularly in relatively high-contrast structures. Therefore, this study aims to propose a feasible protocol that provides satisfactory image quality for diagnosis while minimizing radiation dosage.

Material and methods

CT imaging

One anthropomorphic head phantom consisting of maxillofacial soft-tissue, skull and maxillary sinus (PH-47 Dental Radiography Head Phantom, Kyoto Kagaku, Kyoto, Japan) was used in this study as the standard template (Figure 1). All CT images were obtained by using a 320-slice MDCT scanner (Aquilion ONE, Toshiba Medical System, Otawara, Japan) with 320 × 0.5 mm collimations, tube voltage of 80, 120 and 135 kVp, tube current from 60 to 120 mA with interval of 20 mA. This modality offers two volume scanned modes (whole and local) for oral diagnostic examinations. The whole volume mode utilizes full collimations with 16-cm coverage that enables simultaneous scanning of the maxilla and mandible. Under local volume mode, minified collimations were used instead to match the FOV to acquire either maxillary or mandibular images alone. Besides, we have also acquired the images under helical scan modes using only 80- and 64-rows of the detectors, namely 80S and 64S, with a pitch of 0.896. The 80S is a default protocol recommended by the manufacturer, whereas the 64S is the protocol commonly used for dental examinations [9, 10]. All raw data sets were then reconstructed at 1-mm slice thickness in 1-mm increments by using both bone and soft-tissue reconstruction algorithm. By using multiplanar reformation, the coronal and sagittal images were reconstructed from axial images with different scanning protocols.

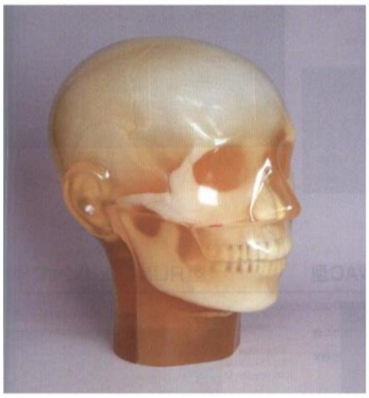

Figure 1: Photographic image describes the PH-47 Dental Radiography Head Phantom with entire maxillofacial soft-tissue, skull and sinuses.

Effective dose estimated for CTDI method was determined using the volume CT dose index ($CTDI_{vol}$), as provided by the scanner. The dose-length product is defined as the volume CT dose index multiplied by scan length, and is an indicator of the integrated radiation dose of an entire CT examination. An approximation of the effective dose was obtained by multiplying the dose-length product by a conversion factor, *k* (equal to 0.0019 mSv mGy^{-1} cm^{-1} for head) [11].

Quantitative image analysis

The images were subjectively evaluated by two board certified radiologists with sub-specialty of head and neck imaging for more than 8 years of experiences in terms of visualization of the anatomical landmarks for diagnosis of bone (delineation of outer cortical/marginal bone plates, enamel and dentin) and soft-tissue (inferior border of maxillary sinus and pulp cavity). We have measured the enamel, dentin and the pulp cavity for both the maxillary and mandibular regions. The observers determined the quality of the images and they were blinded to the settings of tube voltage (kVp), tube current (mA) and scanning mode. The following routine display windows presenting were used: window center of 600 Hounsfield Units (HU) and window width of 3200 HU for bone structures and window center of 50 HU and window width of 350 HU for soft-tissue structures. A 4-grade scale system for image quality was used with 3: excellent; 2: good; 1: fair and 0: non-diagnostic (Figure 2 for bone structures; Figure 3 for soft-tissue structures). We considered a score of 2 as sufficient for diagnostic purposes for bone and soft-tissue structures. The averaged scores were calculated for each landmark at various exposure conditions.

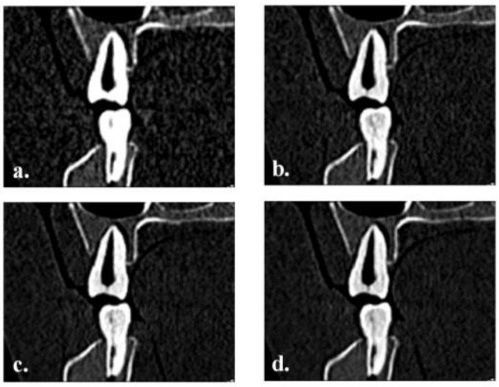

Figure 2: Quantitative measurements were presented image interpretation of (a) score 0, (b) score 1, (c) score 2 and (d) score 4 for bone structures (on enamel regions).

Figure 3: Quantitative measurements were presented image interpretation of (a) score 1, (b) score 2 and (c) score 3 for soft-tissue structures (on pulp cavity regions).

Qualitative image analysis

To evaluate qualitative image quality, fuzzy C-means (FCM) clustering algorithm [12] was performed on segmentation of bone structures (enamel and dentin) and soft-tissue structures (bilateral maxillary sinus and pulp cavity) for each image. Signal difference-to-noise ratio (SdNR) measurements from these regions of interest (ROIs), which are considered a valuable tool in the optimization of exposure parameters [13], were calculated as

$$SdNR = \frac{mean(ROIs) - mean(background)}{\sqrt{\frac{SD(ROIs)^2 + SD(background)^2}{2}}}$$

where SD indicates the standard deviation, and the background is an arbitrary ROI of approximately 1200 pixels surrounding the phantom.

Optimization of tube voltage, tube current and scan mode was based on the figure of merit (FOM), which was defined as follows:

$$FOM = \frac{averaged\ score \times SdNR^2}{effective\ \ dose}$$

Statistical analysis

Agreement in quantitative evaluation was analyzed by using inter- or intra-observer κ statistics computed from the 4-grade categorical scores. κ describes the agreement between categorical results of paired diagnostic ratings, taking into account only agreement beyond that expected by chance [14, 15], as follows:

$$\kappa = \frac{P_0 - P_C}{1 - P_C}$$

where P_0 and P_C represent the proportion of observed agreement and the proportion of agreement expected by chance, respectively.

We used the standards for κ statistic strengths proposed by Landis and Koch [16] ($\kappa \leq 0$ indicates poor agreement; $0.01 \leq \kappa \leq 0.20$, slight agreement; $0.21 \leq \kappa \leq 0.40$, fair agreement; $0.41 \leq \kappa \leq 0.60$, moderate agreement; $0.61 \leq \kappa \leq 0.80$, substantial agreement; and $0.81 \leq \kappa \leq 1.00$, almost perfect agreement).

Between any arbitrary pair of parameter settings (tube voltage or tube current), two-way analysis of variance and Student t-test were used to assess the mean resultants of quantitative and qualitative analyses for both bone and soft-tissue structures. A P value of < 0.025 (0.05/2) was considered to indicate a statistically significant difference [17]. The FOM data were also analyzed using ordinal logistic regression (OLR). OLR fits, in essence, a binary logistic regression model for each cumulative logit; there, odds ratios (OR) can be used for interpretation purposes [18].

Results

Quantitative image analysis

Intra-observer variability of each reader ranged at substantial agreement (weighted kappa 0.63-0.72). Inter-observer variability ranged at substantial agreement as well with weighted kappa of 0.67-0.83 for reader 1 and that 0.77-0.79 for reader 2, respectively.

No significant differences were observed among the four scan modes for both bone and soft-tissue structures. There were significant differences in the diagnostic quality scores among all three tube voltage settings with p value < 0.0001 for both bone and soft-tissue structures. Meanwhile, significant differences were noted on tube current settings for both bone and soft-tissue structures, particularly in the cases of, for bone structure, scores between 120 mA and 60 mA for whole volume scan (P = .021), local volume scan (P = .019), 80S (P = .001) and 64S (P = .015), and scores between 100 mA and 60 mA for 80S (P = .012). For soft-tissue structures, statistically significant differences were found between all pairs of settings: 120 mA vs 60 mA for whole volume scan (P = .016), 80S (P = .003) and 64S (P = .001), 120 mA vs 80 mA for 80S (P = .022) and 100 mA vs 60 mA for 64S (P = .008). Above results demonstrated that settings of tube voltage play a more decisive role, in relative to tube current settings or even scanned modes, to generate substantial influences on image quality due to the increased quantum noises.

Qualitative image analysis

For tube current settings, no significant differences were found under whatever SdNRs of bone structure or soft-tissue structure regions estimated. Whereas, tube voltage setting of 80 kVp was shown to have worst qualitative result as compared with that of both 135 kVp and 120 kVp in bone and soft-tissue structures (all P < .001). In qualitative analysis, significant differences were also observed under different scanned modes: for bone structures, 80S vs whole volume mode (P = .003) and that vs local volume mode (P < .001) and 64S vs whole volume mode (P = .007) and that vs local volume mode (P = .003), and for soft-tissue structures, 80S vs whole volume mode (P = .004) and that vs local volume mode (P < .001). It indicated that 80S or 64S mode with pitch of 0.896 have potential capability to improve image quality; nevertheless, radiation doses (ranged of 0.21-0.99 mSv) were approximately two times higher than that of using whole or local volume mode (0.11-0.47 mSv). Thus in overall performance, the FOM values under 80 kVp as comparing to those under either 120 kVp or 135 kVp (P < .001) were significantly the lowest for bone structures because quantitative scores of zero were recorded by two readers (Figure 4). Meanwhile, no statistical difference occurred under various tube current settings (P =.044). Under both helical modes, the FOM performances were inferior to those under either whole volume or local volume modes (P < .001). For soft-tissue structures, no significant difference was revealed among all tube voltage settings (P =.036). 60 mA showed relatively better performances than 120 mA (P = .002).

64S obtained worst FOM values than either whole or local modes (P < .001). When comparing the overall performance of different scan modes to the standard recommended protocol, it was found that the FOM values from whole and local volume modes were superior to the FOM by 80S mode, with OR estimation of 6.7 and 6.8, respectively. In contrast, 64S showed much inferior performances, being 0.25 times more likely to receive poor overall interpretation (mainly due to higher radiation dose) than 80S.

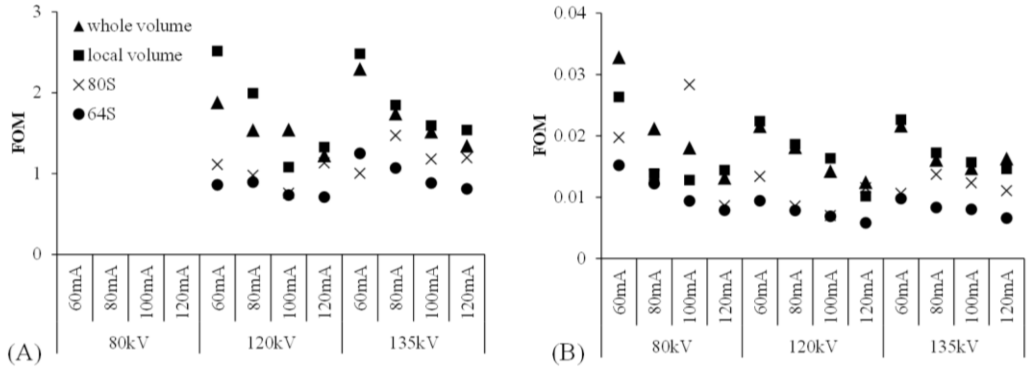

Figure 4: FOM performance at different tube voltages and tube currents in the four scan modes for (A) bone structures, and (B) soft-tissue structures, respectively.

Conclusion

In conclusion, the tube voltage, rather than tube current, is a key determinant of radiation dose in dentomaxillofacia region by 320 MDCT. The fine tune of the tube voltage followed by tube current in our proposed parameters (135 kVp and 80 mA) has shown to provide sufficient reduction of radiation dose without much loss of image quality.

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附件二

科技部補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現（簡要敘述成果是否有嚴重損及公共利益之發現）或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

　　■達成目標

□ 未達成目標（請說明，以 100 字為限）

　　□ 實驗失敗

　　□ 因故實驗中斷

　　□ 其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 ■未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 □無

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其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性），如已有嚴重損及公共利益之發現，請簡述可能損及之相關程度（以 500 字為限）

本研究已成功探討高階電腦斷層掃描儀，於牙科臨床檢查之影像品質與輻射劑量之研究，並投稿於國際期刊上；接續研究希冀探討使用高階雙能量電腦斷層掃描儀，是否可利用此優化參數，以有效提升影像品質並直接減少金屬假影，以達到臨床使用此檢查時的診斷植牙術後評估與追蹤帶來準確診斷判讀依據。

科技部補助計畫衍生研發成果推廣資料表

日期:2016/02/16

科技部補助計畫	計畫名稱: 探討多切面電腦斷層掃描於牙科醫學造影之影像品質與輻射劑量最適化研究：由64切至320切
	計畫主持人: 蔡佳容
	計畫編號: 103-2314-B-040-023- 學門領域: 放射線及核子醫學

無研發成果推廣資料

103年度專題研究計畫研究成果彙整表

計畫主持人：蔡佳容	**計畫編號：**103-2314-B-040-023-

計畫名稱：探討多切面電腦斷層掃描於牙科醫學造影之影像品質與輻射劑量最適化研究：由64切至320切

成果項目			量化：實際已達成數（被接受或已發表）	量化：預期總達成數（含實際已達成數）	量化：本計畫實際貢獻百分比	單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%	篇	
		研討會論文	0	0	100%	篇	
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%	件	
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%	人次	
		博士後研究員	0	0	100%	人次	
		專任助理	0	0	100%	人次	
國外	論文著作	期刊論文	0	1	100%	篇	已投稿至BJR國際期刊接受審查
		研究報告/技術報告	0	0	100%	篇	
		研討會論文	0	0	100%	篇	
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%	件	
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%	人次	
		博士後研究員	0	0	100%	人次	
		專任助理	0	0	100%	人次	
其他成果（無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體		無					

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<tr><td colspan="2">效益事項等，請以文字敘述填列。）</td><td colspan="2"></td></tr>
<tr><td></td><td>成果項目</td><td>量化</td><td>名稱或內容性質簡述</td></tr>
<tr><td rowspan="8">科教處計畫加填項目</td><td>測驗工具(含質性與量性)</td><td>0</td><td></td></tr>
<tr><td>課程/模組</td><td>0</td><td></td></tr>
<tr><td>電腦及網路系統或工具</td><td>0</td><td></td></tr>
<tr><td>教材</td><td>0</td><td></td></tr>
<tr><td>舉辦之活動/競賽</td><td>0</td><td></td></tr>
<tr><td>研討會/工作坊</td><td>0</td><td></td></tr>
<tr><td>電子報、網站</td><td>0</td><td></td></tr>
<tr><td>計畫成果推廣之參與（閱聽）人數</td><td>0</td><td></td></tr>
</table>

科技部補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

   ■達成目標

   □未達成目標（請說明，以100字為限）

   □實驗失敗

   □因故實驗中斷

   □其他原因

   說明：

2. 研究成果在學術期刊發表或申請專利等情形：

   論文：□已發表 ■未發表之文稿 □撰寫中 □無

   專利：□已獲得 □申請中 ■無

   技轉：□已技轉 □洽談中 ■無

   其他：（以100字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以500字為限）

   本研究已成功探討高階電腦斷層掃描儀，於牙科臨床檢查之影像品質與輻射劑量之研究，並投稿於國際期刊上；接續研究希冀探討使用高階雙能量電腦斷層掃描儀，是否可利用此優化參數，以有效提升影像品質並直接減少金屬假影，以達到臨床使用此檢查時的診斷植牙術後評估與追蹤帶來準確診斷判讀依據。