原文題目(出處)：	An innovative approach in osteoporosis opportunistic screening by the dental practitioner: the use of cervical vertebrae and cone beam computed tomography with its viewer program. Oral Surg Oral Med Oral Pathol Oral Radiol 2015;120:651-9
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報告日期：	2017/01/05

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Introduction

- To investigate the use of cone beam computed tomography (CBCT) for predicting osteoporosis based on the cervical vertebrae CBCT-derived radiographic density (RD) using the CBCT-viewer program
- Osteoporosis is a major public health problem. It is a skeletal disease characterized by low bone mass, deterioration (惡化) of the bone structure, and an increased risk of fracture
- Dental radiographs may offer an opportunity to detect osteoporosis and have been suggested as a screening tool for the disease
- The CBCT technique has many advantages. It offers 2- and 3-dimensional images for the radiographed area at a relatively low cost compared with multidetector computed tomography (MDCT)
- We decided to test whether CBCT images can predict osteoporosis in menopausal and postmenopausal women by using the associated CBCT viewer program

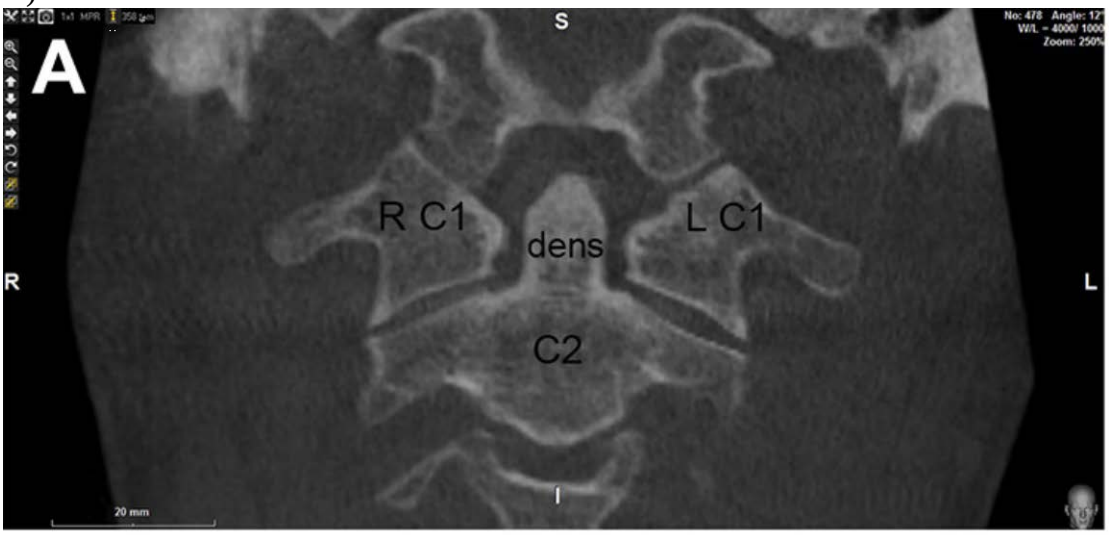
METHODS AND MATERIALS

- CBCT scans (WhiteFox, de Gotzen S.r.l device, distributed by Satelec-Acteon Group, Italy) and dual-energy X-ray absorptiometry examinations of 38 women who participated in an earlier investigation were examined. A coronal slice, subjectively determined from the cervical vertebrae, was selected and the RD as gray values for the first and second vertebrae, and the dens was calculated by using CBCT-viewer software (WhiteFox imaging)
- Study design
  - The sample sizes of 38 menopausal and postmenopausal women were estimated to detect a correlation coefficient of 0.4 and greater (medium and strong) between the cervical vertebrae CBCT-derived RD values and lumbar vertebrae and femoral neck T-scores
  - This calculation set the power of the test at 80% and the level of

significance at 5%

- Patients
  - The present study was part of a larger study that aimed to investigate the changes in the jawbones by an advanced imaging technique (CBCT) among women with osteoporosis and those without, and the effect of osteoporosis medications on periodontal health
  - A secondary aim of this study was to investigate whether other structures that appear with jawbone scanning (e.g., cervical vertebrae) in dental CBCT images can be a better predictor of osteoporosis compared with the jawbones
  - The dental CBCT images taken by Barngkgei et al. for the previous investigation of 38 Syrian (敘利亞) women (age range 47-75 years [mean ¼ 57.9 (SD ¼ 7.2)]) referred for a dual-energy X-ray absorptiometry (吸光光度法) examination by their physicians in Alassad Hospitale Damascus University in 2012, were analyzed in the present study
  - Patients with diabetes, thyroid disorders, and bone diseases other than osteopenia or osteoporosis were excluded. None of the included women consumed alcohol; only 3 (7.9%) were smokers, and their smoking durations were 12, 18, and 40 years. None of participants had suffered a previous fracture in either the lumbar vertebrae or the femoral neck
  - Using the World Health Organization (WHO) criteria, participants were classified according to their lumbar T-scores and femoral neck T-scores into 3 groups. Group A included women with healthy bone mineral density (BMD) values (T-score □□1). Group B included women with osteopenia (□2.5 < T-score <□1). Group C included women with osteoporosis (T-score 2.5)
- Radiographic devices and analysis software
- 硬體
  - The dual-energy X-ray absorptiometry examination was performed using a DXA scanner (Hologic Discovery QDR, Hologic Inc., Bedford 01730, MA)
  - The tube current, tube voltage, and exposure time were preset at 9 mA, 105 kV, and 9 seconds; respectively. This device uses a pulsed mode acquisition.
  - The effective dose from these parameters was about 100 mSV (manufacturer's information)
  - The CBCT images were taken using WhiteFox (de Gotzen S.r.l device, distributed by Satelec-Acteon Group Italy)
  - The FOV and the voxel size were set at 13 □15 cm and 0.25 mm
  - The tube current, tube voltage, and exposure time were preset at 9 mA, 105 kV, and 9 seconds; respectively
  - This device uses a pulsed mode acquisition. The effective dose from these parameters was about 100 mSV (manufacturer's information)
- 軟體
  - The viewer software (WhiteFox Imaging, V3; developed by the same CBCT manufacturer) was used to analyze the CBCT images. This software is used by dentists to open and study CBCT scans because it contains basic tools (e.g., radiographic density calculator) and is also considered user-friendly. A personal laptop (Fujitsu, Lifebook AH 530) running Microsoft Windows 7 as an operating system was used to study and analyze the CBCT scans
- Analysis of the CBCT scans

- The angulations of selected slices were adjusted manually to reduce the differences in head position among participants. This was done by navigating through the coronal slices at the mental foramen area to make the axial slices parallel to the plane that passes through the inferior border of both the right and left mental foramina
- The coronal slice that passes through the middle of the dens (the odontoid process of the second cervical vertebra) was selected in each CBCT scan. Both the first and second vertebrae in the selected slice were analyzed. In this slice, the first vertebra appears divided into 2 parts; right and left (下圖 A)



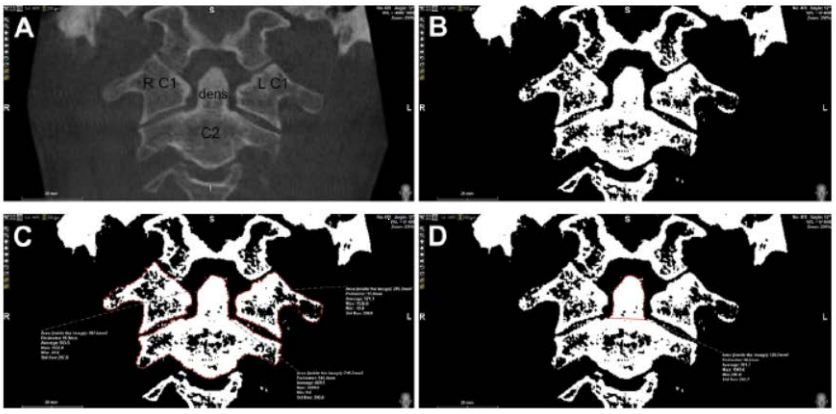


Fig. 1. **A**, The selected coronal slice after angulation adjustment of the cone beam computed tomography (CBCT) image. The right (R C1) and left (L C1) parts of the first and the second vertebrae (C2) with its odontoid process (dens) appear in this slide. **B**, Adjusting the window width and level to 0 and 400 gray values, respectively. **C**, Calculating the radiographic density (RD) of the left and right parts of the first and the second vertebrae. **D**, the dens.

- To standardize & make the borders clearer: window width was adjusted to zero
- Window level of 400 gray values was subjectively chosen after attempts were made to find a suitable window level by using different window level values and comparing them with the default window width and level (4000 and 1000 gray values, respectively)
- White indicated the bone tissue and black indicated all other tissues

- The interscan RD homogeneity was tested by using distilled water
- The CBCT-derived RD values were calculated for the first and second vertebrae and the dens using the “measure polygon” tool with a magnification factor of 250%. The RD values of each side of the first vertebra were calculated separately

- Main examiner 分析後，隨機挑選 4 個 case，由放射科醫師再行分析，以建立 interexaminer agreement，而本研究之分析數據只採用 main examiner

- Statistical analysis
  - Interclass correlation was carried out to assess intraexaminer and interexaminer agreement
  - Analysis of variance (ANOVA) tests and post hoc comparisons with Bonferroni correction were performed to investigate whether the differences in CBCT-derived RD values of the cervical vertebrae were statistically significant among the three study groups
  - Pearson correlation test was performed to estimate the strength of the correlation between cervical vertebrae RD values and lumbar vertebrae and femoral neck T-scores
  - Correlation coefficient values:
    - No correlation (0 < r □0.2)
    - Weak (0.2 < r □0.4)
    - Medium (0.4 < r <0.7)
    - Strong (r >□0.7)
  - The diagnostic accuracy test (receiver operating characteristic analysis) was performed to determine the validity (有效性) of cervical vertebrae CBCT-derived RD gray values as a screening tool for femoral neck and lumbar vertebrae osteoporosis and decreased BMD
    - characteristic analyses

- sensitivity
- specificity
- positive predictive values
- negative predictive values
- positive likelihood ratio
- negative likelihood ratio

RESULTS

- The characteristics of the present study patients

Table I. Age and body mass index (BMI) of the study patients (n = 38)

Groups	*Age (y), Mean (SD)*	*BMI, Mean (SD)*
Groups according to the lumbar T-score		
Healthy (n = 10)	52.3 (3.5)	29.7 (5.3)
Osteopenia (n = 15)	59.1 (7.2)	31.7 (8.2)
Osteoporosis (n = 13)	60.9 (7.1)	28.5 (3.1)
Groups according to the femoral neck T-score		
Healthy (n = 17)	55.1 (4.6)	31 (7.5)
Osteopenia (n = 11)	58.1 (8.8)	30.4 (5.4)
Osteoporosis (n = 10)	62.6 (6.9)	28.4 (4.2)

- Descriptive data of the cervical vertebrae CBCT-derived RD values in each group
  - There were statistically significant differences in the cervical vertebrae CBCT-derived RD values among the three groups

Table II. Description of the cervical vertebrae cone beam computed tomography (CBCT)-derived radiographic density (RD) values as gray values for healthy, osteopenic, and osteoporotic groups (mean [SD]) and the result of ANOVA test and post hoc comparisons with Bonferroni correction (n = 38)

	According to lumbar T-score			*According to femoral neck T-score*		
Variable	*Healthy*	*Osteopenia*	*Osteoporosis*	*Healthy*	*Osteopenia*	*Osteoporosis*
Right C1 vertebral GV	585 (90)	427 (58)*	361 (84)	503 (106)	445 (105)*	352 (87)
Left C1 vertebral GV	589 (127)	456 (59)*	376 (86)	533 (117)	446 (94)*	364 (74)
C2 vertebral GV	686 (69)	557 (92)†	438 (130)‡	619 (104)	532 (139)†	452 (135)
C2-Dens GV	882 (165)	701 (87)*	545 (109)§	787 (150)	692 (169)*	543 (115)

Numbers are rounded to whole numbers.
ANOVA test indicated statistical significant differences in all cervical vertebrae CBCT-derived RD values among the present study three groups. Only significant differences according to post hoc comparisons with Bonferroni correction were reported.
C, cervical; *GV*, gray value.
*Significantly different from the healthy group ($P < .005$).
†Significantly different from the healthy group ($P < .05$).
‡Significantly different from the osteopenic group ($P < .05$).
§Significantly different from the osteopenic group ($P < .005$).

- Interclass correlation coefficients of the interexaminer and intraexaminer agreement for measuring the dens RD were 0.94 and 0.98, respectively, indicating excellent agreements
- The strength of the correlation between the cervical vertebrae RD values and the T-scores of the lumbar vertebrae and the femoral neck
  - Strongest correlation:
    The dens CBCT-derived RD values / lumbar T-scores (r ¼ 0.747).
  - Strong correlations:

first and second vertebrae RD values / lumbar T-scores

- Medium correlations:
  all cervical vertebrae RD values / femoral neck T-scores (r ¼ 0.5-0.6)

Table III. Pearson correlation coefficients (r) of the associations between the cervical vertebrae cone beam computed tomography (CBCT)-derived radiographic density (RD) values and the T-scores of the lumbar vertebrae and femoral neck (n = 38)

Variable	*Lumbar vertebrae T-score*	*Femoral neck T-score*
Right C1 vertebral GV	0.703 ($P < .001$)	0.516 ($P = .001$)
Left C1 vertebral GV	0.728 ($P < .001$)	0.590 ($P < .001$)
C2 vertebra GV	0.746 ($P < .001$)	0.504 ($P = .001$)
C2-Dens GV	0.747 ($P < .001$)	0.522 ($P = .001$)

C, cervical; *GV*, gray value.

- The validity of cervical vertebrae CBCT-derived RD as a screening tool for osteoporosis
  - The sensitivity, specificity, and accuracy of all cervical vertebrae RD values, except those related to the left part of the first cervical vertebrae, were higher in predicting lumbar T-scores than in predicting femoral neck T-scores
  - Taking into account sensitivity, specificity, accuracy, and positive and negative likelihood ratios
    - the dens RD values were the best cervical vertebrae RD values in predicting lumbar vertebrae osteoporosis
    - the CBCTderived RD values of the left part of the first cervical vertebrae were the best cervical vertebrae RD values in predicting the femoral neck osteoporosis

Table IV. The validity of the cervical vertebrae cone beam computed tomography (CBCT)-derived radiographic density (RD) as a screening tool for femoral neck and lumbar vertebrae osteoporosis

Area	*Variable*	*AUC (95% CI)*	*Cutoff value**	*Sen*	*Spec*	*PPV*	*NPV*	*+LR*	*−LR*
Lumbar vertebrae	Right C1 vertebral GV	0.845 (0.709-0.980)	383	76.9%	88%	76.9%	89.3%	7.18	0.26
	Left C1 vertebral GV	0.846 (0.712-0.980)	424	76.9%	84%	71.4%	87.5%	4.81	0.27
	C2 vertebral GV	0.865 (0.712-0.999)	475	84.6%	88%	78.6%	91.7%	7.05	0.17
	C2-Dens GV	0.908 (0.805-0.999)	600	76.9%	92%	83.3%	88.5%	9.6	0.25
Femoral Neck	Right C1 vertebral GV	0.832 (0.679-0.985)	383	80%	82.1%	61.5%	92%	4.48	0.24
	Left C1 vertebral GV	0.864 (0.737-0.991)	391	70%	92.9%	77.8%	89.7%	9.8	0.32
	C2 vertebral GV	0.779 (0.592-0.965)	560	90%	67.9%	50%	95%	2.8	0.15
	C2-Dens GV	0.857 (0.732-0.982)	698	100%	57.1%	45.5%	100%	2.33	0

AUC, area under the curve (accuracy); *Sen*, sensitivity; *Spec*, specificity; *PPV*, positive predictive value; *NPV*, negative predictive value; *+LR*, positive likelihood ratio; *−LR*, negative likelihood ratio.
*In gray values. Rounded to whole numbers.

- The validity of cervical vertebrae CBCT-derived RD as a screening tool for decreased BMD
  - The sensitivity, specificity, and accuracy of all cervical vertebrae RD values, except those related to the left part of the first cervical vertebrae, were higher in predicting lumbar T-scores than in predicting femoral neck T-scores
  - Taking into account sensitivity, specificity, accuracy, and positive and negative likelihood ratios
    - the right part of the first cervical vertebrae CBCT-derived RD values were the best cervical vertebrae RD values in predicting lumbar vertebrae decreased mineral density
    - whereas the RD values of the left part of the first cervical vertebrae were the best cervical vertebrae RD values in predicting the femoral neck decreased mineral density

Table V. The validity of the cervical vertebrae cone beam computed tomography (CBCT)-derived radiographic density (RD) as a screening tool for femoral neck and lumbar vertebrae decreased mineral density

Area	*Variable*	*AUC (95% CI)*	*Cutoff value**	*Sen*	*Spec*	*PPV*	*NPV*	*+LR*	*−LR*
Lumbar vertebrae	Right C1 vertebral GV	0.968 (0.917-0.999)	512	92.9%	90%	96.3%	81.8%	9.29	0.08
	Left C1 vertebral GV	0.893 (0.759-0.999)	534	92.9%	80%	92.9%	80%	4.64	0.09
	C2 vertebral GV	0.911 (0.815-0.999)	635	89.3%	90%	96.2%	75%	8.93	0.12
	C2-Dens GV	0.889 (0.771-0.999)	697	71.4%	90%	95.2%	52.9%	7.14	0.32
Femoral Neck	Right C1 vertebral GV	0.773 (0.622-0.924)	445	81%	70.6%	77.3%	75%	2.75	0.27
	Left C1 vertebral GV	0.812 (0.678-0.947)	424	61.9%	94.1%	92.9%	66.7%	10.52	0.4
	C2 vertebral GV	0.765 (0.611-0.918)	560	71.4%	82.4%	83.3%	70%	4.05	0.35
	C2-Dens GV	0.787 (0.641-0.934)	687	76.2%	76.5%	80%	72.2%	3.24	0.31

AUC, area under the curve (accuracy); *Sen*, sensitivity; *Spec*, specificity; *PPV*, positive predictive value; *NPV*, negative predictive value; *+LR*, positive likelihood ratio; *−LR*, negative likelihood ratio.
*In gray values. Rounded to whole numbers.

- The CBCT-derived RD values of the dens and the left part of the first cervical vertebra showed the strongest correlation coefficients (r ¼ 0.7, 0.6; P < .001) and the highest sensitivity (76.9%, 70%), specificity (92%, 92.9%), and accuracy (90.8%, 86.4%) in predicting osteoporosis in the lumbar vertebrae and the femoral neck, respectively

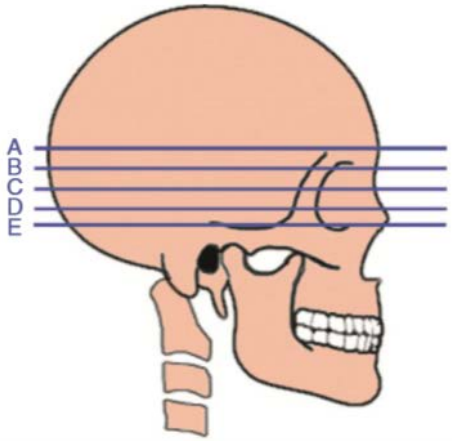
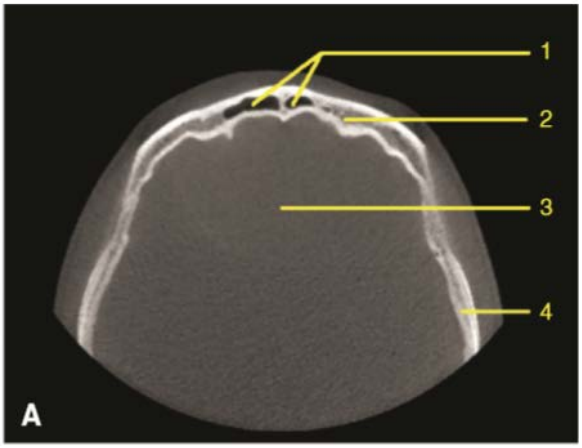
DISCUSSION

- The present study suggests that cervical vertebrae CBCT-derived RD values can predict osteoporosis status in menopausal and postmenopausal women with use of the associated CBCT-viewer program
- 是為一大進展!
- 廠商可考慮在 CBCT 軟體中增加自動提醒牙醫師病患有骨質疏鬆的機制。
- 由 the cervical vertebrae RD values and the lumbar T-scores 的關聯性大於 cervical vertebrae RD values and the femoral neck T-scores 的關聯性可推測: cervical and lumbar vertebrae are both trabecular in nature and affected by menopause more than cortical bone
- 相較於 Koh and Kim 學者以 mandible 作為研究，本篇的 cervical vertebrae 更能分辨 healthy women, women with osteopenia, and women with osteoporosis
- The RD values of the dens and the left part of the first cervical vertebrae were best in predicting the lumbar and femoral neck osteoporosis
- Drawbacks:
  - Gray value inaccuracy was found to be worse in small FOVs
  - The reliability of the CBCT gray values varies between the studies that have used them as an assessment tool for bone quality
  - The gray value calculation was highly homogeneous for all patients.

However, this variation differs at different window levels

CONCLUSIONS

- Cervical vertebrae appear frequently in many dental radiographs
- CBCT-derived RD of cervical vertebrae can predict osteoporosis status using a CBCT-viewer program
- This finding should be confirmed on other CBCT devices

題號	題目
1	右圖中 1 為何   (A) Frontal sinus (B) Anterior cranial fossa (C) Crista galli (D) Optic canal
答 案 (A)	出處：Oral Radiology - Principles and Interpretation, 7E (2014) p221
題號	題目
2	何者不是 CBCT 常見的 IMAGE ARTIFACTS (A) PATIENT MOTION ARTIFACTS (B) INTRODUCED ARTIFACTS (C) INHERENT ARTIFACTS (D) PROCEDURE-RELATED ARTIFACTS (E) OPERAOR MOTION ARTIFACTS
答 案 (E)	出處：Oral Radiology - Principles and Interpretation, 7E (2014) CH 11