歯科用コーンビームCT画像を用いた下顎骨皮質骨の自動解析に関する研究

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要旨

歯科用 Cone Beam Computed Tomography (CBCT) は，歯科領域において，幅広く利用されている．下顎骨皮質骨の骨質の客観的な指標として，mandibular cortical width (MCW)， computed tomography mandibular index (CTMI)， computed tomography index (inferior) [CTI(I)]などがある．これらは腰椎骨密度と強い相関があり，女性の骨粗鬆症のスクリーニングに有用とされている．しかしながら，手作業による断面の生成や計測に労力を要する．また，CTMI や CTI(I)は下顎骨下端のみの計測のため，視覚的な骨質評価との不一致が生じるという問題もある．そこで，オトガイ孔近傍の下顎骨解析断面の生成，皮質骨厚計測，皮質骨の骨質解析を自動化し，視覚的評価と一致する客観的な骨質評価を行うことを本研究の目的とした.

歯科インプラント治療のために歯科用 CBCT が施行された患者から成人女性患者 71 名［年齢範囲：20 – 78 歳，　平均：52.4 歳，standard deviation（SD）：16.4］を無作為に抽出し，50 歳で 2 つの群［females younger (FY) と females older (FO)］に分け，computed tomography cortical index (CTCI)［C1: 正常, C2: 軽度粗造化, C3:重度粗造化］によって FO をさらに 3 つの群に分けた．これらに対して，自動計測・解析［平均 voxel value (VV)，coefficient of variation (CV)，interquartile range to median ratio (IQR/Med)］を行った．なお，手動計測の観察者変動は intra class correlation coefficient (ICC) を用いて評価した．皮質骨厚計測や解析値と CTCI による視覚的評価との比較を Bonferroni 補正した Mann-Whitney の U 検定や重み付けカッパ値を用いて行った.

71 症例全例において，下顎骨の自動解析断面の生成，CTMI・CTI(I)の自動計測，及び，皮質骨の自動解析に成功した．自動処理の合計の平均時間は，およそ 38 秒だった．CTCI の全てのカテゴリーで，皮質骨厚の自動計測と手動計測は高い一致を示し (ICC > 0.9)，自動計測の信頼性が確認された．Bonferroni 補正をした Mann-Whitney の U 検定により，FY と FO C3，及び，FO C1 と FO C3 との間で，FO C3 の CTMI，CTI(I) は，共に優位な低値を示した ($p < 0.05$).

一方，自動解析による VV では，FO C1 と FO C2 との間で有意差が認められなかったが，CV，IQR/Med では，FY と FO C3 以外の全ての組み合わせで有意差が認められた ($p < 0.01$)．VV では，ビームハードニングの影響により CTCI との一致度（重み付けカッパ値）は 0.55，対して，CV や IQR/Med では，それぞれ 0.83，0.74 と高い一致を示した．また，皮質骨厚の計測（CTMI）において，FO C3 の 45.5％ が CTCI との不一致を示したのに対して，CV では，FO C 3 の約 80％ が CTCI と一致し，本手法による皮質骨自動解析では，CTCI との一致度が大きく改善された.

下顎骨の特にオトガイ孔近傍直下の皮質骨厚の計測と皮質骨内部性状を評価する自動処理の開発に成功し，視覚的評価とも良く一致する客観的な皮質骨の骨質評価を行うことができた．これにより，骨粗鬆症のスクリーニングを自動で行うことが可能になり，また，今後，インプラント治療の術後予後のための骨質評価としても利用されることが期待される.

Automatic analysis of mandibular cortical bone on cone-beam computed tomography

（歯科用コーンビーム CT 画像を用いた下顎骨皮質骨の自動解析に関する研究）

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Abstract

Cone-beam computed tomography (CBCT) has been widely used in various dental applications. The computed tomography cortical index (CTCI) and computed tomography mandibular index (CTMI) or computed tomography index (inferior) [CTI(I)] are well known as subjective and objective assessments of the mandibular cortex quality for osteoporosis or implant planning, respectively. The mandibular cortex width has a strong correlation with lumbar bone mineral density and has been used for osteoporosis screening in women. However, it requires considerable labor to manually generate cross-sectional images and measure the cortex width. In addition, CTMI and CTI(I) measure only the inferior border of the mandible, which may cause discrepancies with CTCI. The aim of this study was to automate the generation of cross-sectional images, cortical bone thickness measurement, and cortical bone quality analysis around the mental foramen, and to evaluate the cortex quality consistent with subjective assessment.

Seventy-one women were enrolled in this study (mean age: 52.4 years) and were divided into two age groups: female subjects younger (FY) and female subjects older (FO) than 50 years. Moreover, the subjects were subdivided into three CTCI groups (C1: normal, C2: mild/moderate erosion, and C3: severe erosion). Automatic reconstruction, measuring the cortex width in all the mandibular bones inferior to the mental foramen (MF) and analyses (VV, voxel value; CV, coefficient of variation; IQR/Med, interquartile range to median ratio) were performed. These measurements and analyses were compared with manual measurements and CTCI. The inter-/intra- observer agreements of manual measurement were assessed using the intraclass correlation coefficient (ICC). The agreements between automatic measuring or analyses and CTCI were calculated using the weighted Cohen’s kappa. The relationships between automatic analysis and CTCI were assessed using the Mann-Whitney U test with Bonferroni correction.

In all 71 cases, automatic reconstruction, measurement of the cortex width, and analyses were successful without any error. The mean total processing time was approximately 38 s. In each CTCI type, automatic and manual measurements showed high agreement and reliability (ICC > 0.9). Predominantly lower values for both CTMI and CTI(I) were found in FY-FO C3 and FO C1 - FO C3 ($p < 0.05$). In automatic mandibular cortex analyses, there were no significant differences between FO C1 and FO C2 in VV, whereas in CV and IQR/Med, significant differences were found in all combinations except between FY and FO C3 ($p < 0.01$). In the VV, the agreement with CTCI by weighted kappa values was not as high as 0.55 because of the effect of beam hardening, but the agreement with CTCI by CV and IQR/Med was high at 0.83 and 0.74, respectively. On the measurement of cortical bone thickness (CTMI), 45.5 % of FO C3 showed disagreement with the CTCI, whereas about 80% of FO C3 showed agreement with the CTCI. The agreement with the CTCI was well improved by automatic cortical bone analysis using this method.

The new method could drastically reduce the routine clinical workload for assessment of mandibular cortex quality, and it could be useful as a screening tool for osteoporosis or implant planning.