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Original Article

ผลของชนิดไทเทเนียมที่ใช้ทำรากฟันเทียมต่อความแม่นยำของการวัดเชิงเส้นและระดับสีเทาของกระดูกเบ้าฟันโดยใช้เครื่องถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีม

Effect of titanium grade of dental implants on accuracy in linear and gray level measurement of alveolar bone using cone beam computed tomography.

สุวดี โฆษิตบวรชัย

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บทคัดย่อ การศึกษานี้มีวัตถุประสงค์เพื่อเปรียบเทียบความสูง ความหนา และระดับสีเทาของกระดูกเบ้าฟันด้วยภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีม ระหว่างกลุ่มที่ฝังและไม่ได้ฝังรากฟันเทียม โดยทำการฝังรากเทียมด้วยวัสดุ 2 ชนิดลงในกระดูกเบ้าฟันบริเวณฟันกรามน้อยล่างของร่างมนุษย์จำนวน 5 ร่าง ทำการถ่ายภาพชิ้นกระดูกขากรรไกรล่าง 3 ครั้ง ด้วยเครื่อง WhiteFox(R) scanner โดยไม่มีรากฟันเทียม และมีรากฟันเทียมที่ทำจากไทเทเนียมเกรด 4 และ 5 ทำการวัดความสูงและความหนาของกระดูกบริเวณรอบรากฟันเทียมจากภาพรังสีแต่ละภาพและเปรียบเทียบโดยใช้สถิติทีชนิดจับคู่ จากนั้นทำการวัดระดับสีเทารอบรากฟันเทียมที่ด้านใกล้กลาง ใกล้ลิ้น ไกลกลาง และใกล้กระพุ้งแก้มที่ระยะ 0.5 มม. 1 มม. และ 2 มม. จากนั้นทำการเปรียบเทียบร้อยละของความแตกต่างของค่าเฉลี่ยโดยใช้การวิเคราะห์ความแปรปรวนแบบทางเดียว ผลการศึกษาพบว่าไทเทเนียมเกรด 4 ทำให้ความสูงของกระดูกมีการเปลี่ยนแปลงเพิ่มขึ้นร้อยละ 2.03 และความหนาของกระดูกลดลงร้อยละ 2.48 ไทเทเนียมเกรด 5 ทำให้ความสูงของกระดูกเพิ่มขึ้นร้อยละ 1.52 และความหนาของกระดูกลดลงร้อยละ 1.41 ซึ่งความหนาของกระดูกในกลุ่มไทเทเนียมเกรด 5 มีความแตกต่างจากกลุ่มอื่นอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) พบค่าระดับสีเทาเพิ่มมากขึ้นที่ด้านใกล้ลิ้นและใกล้กระพุ้งแก้มของรากฟันเทียมและลดลงที่ด้านใกล้กลางและไกลกลางของรากฟันเทียม ร้อยละของความแตกต่างของค่าเฉลี่ยทั้ง 4 ด้านรอบรากฟันเทียมที่ทำจากไทเทเนียมเกรด 4 มีความแตกต่างกันอย่างมีนัยสำคัญ ที่ระยะ 0.5 มม. จากผิวรากฟันเทียม ($p < 0.05$) ในขณะที่กลุ่มไทเทเนียมเกรด 5 แสดงให้เห็นความแตกต่างทั้งที่ระยะ 0.5 มม. 1 มม. และ 2 มม. จากผิวรากฟันเทียม ($p < 0.05$) กล่าวโดยสรุป พบการเพิ่มขึ้นของระดับความสูงและการลดลงของความหนากระดูกในภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ซึ่งเป็นผลจากไทเทเนียมทั้ง 2 ชนิดเล็กน้อย ซึ่งอาจไม่ส่งผลทางคลินิก สิ่งรบกวนรอบรากฟันเทียมทำให้ระดับสีเทาด้านใกล้กระพุ้งแก้มและใกล้ลิ้นของรากฟันเทียมเพิ่มขึ้นและด้านใกล้กลางและไกลกลางลดลง

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Abstract The aim of this study was to compare the bone height, bone thickness and the gray value around the dental titanium implants on cone beam computed tomography (CBCT) images between implant placement and without implant placement. Two types of titanium implant were placed into the premolar area of 5 dry human mandibles. Each mandible was scanned 3 times by a WhiteFox® scanner; without titanium, titanium grade 4 and grade 5 placements. Bone height and bone thickness were measured around the implant site on each radiograph. Paired t-test was used for comparison. The gray values were measured around the implant sites at mesial, lingual, distal, and buccal aspects at 0.5 mm, 1 mm and 2 mm from the implant surface. One-Way ANOVA was used for comparison the mean percent difference of gray values between 4 aspects. For the results, titanium grade 4 produced an increase of 2.03% in bone height and a reduction of 2.48% in bone thickness. Titanium grade 5 produced an increase of 1.52% in bone height and a reduction of 1.41% in bone thickness. Significant difference ($p < 0.05$) was detected in bone thickness of titanium grade 5 when comparing measurements performed with and without implant placement. Increased gray values were found at the lingual and buccal aspects of the implant sites, whereas reduced gray values were found at the mesial and distal aspects of the implant sites. The mean percent difference of gray values at 4 aspects around the titanium grade 4 showed the significant differences at 0.5 mm from the implant surface ($p < 0.05$) while the titanium grade 5 showed the significant differences at 0.5 mm, 1 mm and 2 mm from the implant surface. ($p < 0.05$). For conclusions, An increase in bone height and a reduction in bone thickness of two types of titanium implant on CBCT images hardly produced the significant effect to the implant placement in clinical practice. The artifact around the two types of titanium produced the increased gray values on buccal and lingual aspects while the reduced gray values were seen on mesial and distal aspects of implant sites.

Keywords: cone beam computed tomography, dental implant, titanium, artifact

INTRODUCTION

Cone beam computed tomography (CBCT) is frequently used for the dental implant placement. It is a 3D digital radiography which provides a sharper digital image than conventional tomogram.(1) The radiation dose to the patient is lower than that of multi slice computed tomography (MSCT).(2) Before the dental implant planning, CBCT will be used to evaluate the feature of cortical bone, bone shape, bone height and bone thickness.(3) It is also used to assess the bone density of implant sites.(4) It was claimed to be a reliable technique for the linear measurement of alveolar bone (5, 6) and gray value scan be used to infer bone density and may provide a valuable aid to predict bone quality at potential implant sites.(7) However, metal artifact is one of the limitations of CBCT image. It produces the beam hardening and streak artifacts(8), which can hide the adjacent structures including dimensional distortion from superimposition of metal artifact. Most of the dental implants are constructed from metals or alloys such as titanium and alloy titanium.(9) Therefore, when the second implant will be put near the first implant, the artifacts from the first implant may influence either to an accuracy of alveolar bone measurement or gray scale density measurement at the second implant site. Therefore, the aim of this study was to compare the bone height, bone thickness and the gray values around the two types of dental titanium implant-titanium grade 4 and titanium grade 5 on CBCT images before and after the second implant placement.

MATERIALS AND METHODS

Five dry human mandibles were selected from the Gross Anatomy Laboratory Dissecting room of the department of Anatomy, Faculty of Medicine, Khon Kaen University with following criteria: each mandible aged equal or more than 18 years, presented an alveolar socket at premolar area, socket depth at least 12 mm. and have no any metal restorations. This research was approved by the Khon Kaen University Ethics Committee in human research (HE581072).

CBCT scanning

Each mandible was scanned three times using WhiteFox® scanner (ACTEON, Italy)- flat panel type receptor, tube voltage of 105 kVp, voxel size of 0.1-0.5 mm, scanning time of 18-27 seconds, X-ray exposure time of 6-9 seconds, reconstruction time of 30 seconds and focal spot size of 0.5 mm x 0.5 mm. Before the scanning procedure, the center of the implant site and the upper border of the mental foramen were marked on mandibles by gutta percha no.20 and plastic adhesive tape as the reference points of measurement (Figure1). The mandibles were mounted on supporting plate providing the occlusal plane parallel to the horizontal plane. The implant site was lied in the center of field of view (FOV) sized 60 x 60 mm2 using the laser orientation beam (Figure 2). The voxel size was 2 mm. Before the second scan, the fixture of titanium grade 4 (PW Plus, Nakhon Pathom, Thailand) with the diameter of 4.3 mm. and the height of 12 mm. was placed into the alveolar socket using the screw driver then covered with the cover screw and was scanned with the same procedure as the first time scanning. The third time scanning, the fixture of titanium grade 5 (BioHorizons, London, United Kingdom) with the diameter of 4.6 mm. and the height of 12 mm. was placed into the socket using the screw driver then covered with the cover screw before taking the radiograph with the same procedure as the first and second time scanning. The compositions of titanium implants were shown in table 1.

Figure 1 The upper border of mental foramen (A) and the center of alveolar socket (B) were marked with gutta percha.

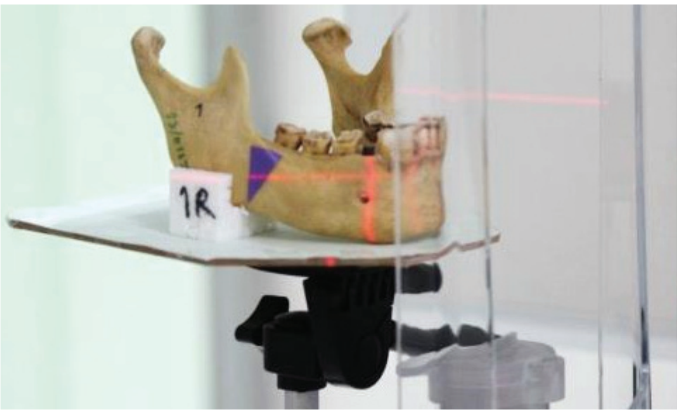

Figure 2 The position of mandible during cone beam CT.

Table 1 The compositions of titanium grade 4 and grade 5 (9)

Titanium	Element							
	N	C	H	Fe	O	Al	V	Ti
Grade 4	0.03	0.10	0.015	0.05	0.40	-	-	Balance
Grade 5	0.05	0.08	0.015	0.30	0.20	5.50-6.75	3.50-4.50	Balance

Radiographic examination

Twenty-four cross-sectional slices were cut from CBCT radiographs around the implant surface of 3.5 mm using *WhiteFox Imaging® Version 3* (ACTEON, Oliate Olona Varese, Italy). Twelve slices were cut anteriorly, and 12 slices were cut posteriorly to the implant site. The distance of each slice was 0.5 mm. The bone height was measured from the upper border of the mental foramen to the upper border of alveolar ridge on the cross sectional view of 24 slices. The bone thickness was measured from the lingual border to the buccal border of alveolar bone through the upper border of mental foramen on the same 24 slices (Figure 3). Both of the bone height and bone thickness were measured two times by two examiners separately and the average was used for the calculation. The gray values were measured on 4 slices on each radiograph along 4 mm. of the implant axis at mesial (M), lingual (L), buccal (B) and distal (D) aspects around the implants at 0.5 mm, 1 mm and 2 mm from the implant surface (Figure 4). To assess the intraobserver reliability, the 10 images of without implant placement were randomly selected and measured twice by each observer. The second session was at least 1 week after the first session. When intra-class correlation coefficient is more than 0.8, the observer will be accepted in the image evaluation (Table 2).

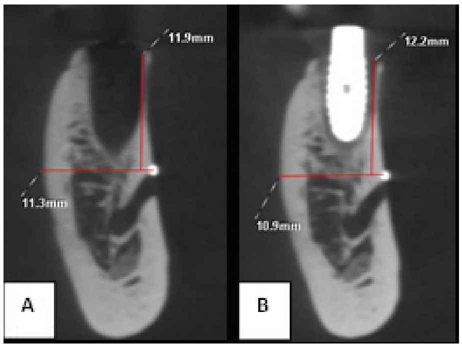

Figure 3 Alveolar bone height and bone thickness measurements in CBCT radiographs before implant placement (A) and after implant placements (B).

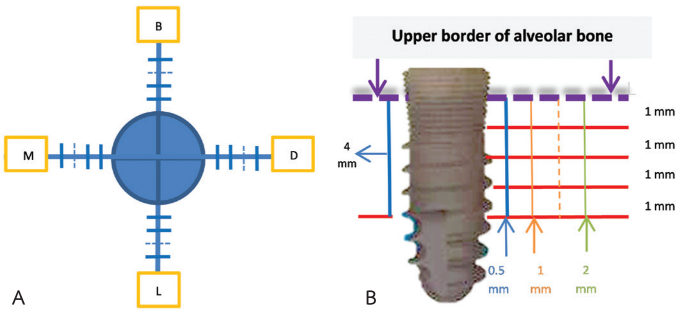

Figure 4 Gray value measurements at mesial (M), lingual (L), buccal (B) and distal (D) aspects around the implants at radius of 0.5 mm, 1 mm and 2 mm from the implant surface (A). Gray value measurements along the axis of implant (B).

Data analysis

Averages of bone height and bone thickness were compared between with and without implant placement by paired-t test using the Stata 10 for Windows (Stata Corp LP, Texas, USA). The data from all five mandibles were calculated under adjusting the clustering effect. Differences of bone height and bone thickness between with and without implant placements were calculated as percentage. Differences of gray value were calculated as percentage using the following formula:

$$\text{percent difference of gray value} = \frac{(\text{Gray value}_{\text{with implant}} - \text{Gray value}_{\text{without implant}})}{\text{Gray value}_{\text{without implant}}} \times 100$$

One – Way ANOVA was used for comparison the mean percent difference of gray values at 4 aspects around the implants at each radius. Intra-class correlation coefficient (ICC) was used to evaluate the interobserver and intraobserver reliability

RESULTS

With regard to alveolar bone measurements, the titanium grade 4 placements produced an increase of 2.03% in bone height and a reduction of 2.48 % in bone thickness. No significant differences ($p > 0.05$) were detected when comparing the measurements taken with and without titanium placement for both parameters (Table 3).

The titanium grade 5 placements produced an increase of 1.52% in bone height and a reduction of 1.41% in bone thickness. Significant difference ($p < 0.05$) was observed in bone thickness measurement when comparing performed with and without implant placement (Table 4). No significant differences ($p > 0.05$) were detected when comparing the measurements taken with titanium grade 4 and titanium grade 5 placements for both parameters (Table 5). Regarding to the gray values, the mean percent difference of gray values at 4 aspects of titanium grade 4 showed the significant difference at 0.5 mm from the implant surface ($p<0.005$) while titanium grade 5 showed the significant differences at 0.5 mm, 1 mm and 2 mm from the implant surface ($p <0.05$) (Table 5). Increased gray values were found on mesial and distal aspects of implant sites, reduced gray values were found on buccal and lingual aspects of implant sites. (Figure 5)

Table 2 Intra-examiner and inter-examiner reliability test of two examiners in bone height.

	Intra-class correlation coefficient (ICC)		
	Bone height	**Bone thickness**	**Gray value**
Examiner 1	0.912	0.926	0.989
Examiner 2	0.943	0.881	1.000
Inter-Examiners	0.885	0.862	0.991

Table 3 Mean alveolar bone height and bone thickness of without and with titanium grade 4 placements.

Alveolar bone measurement		Without titanium	Titanium grade 4	Mean percent difference	95% CI	*p*-value (t-test)
Height	N	120	120			
	Mean (mm.)	13.7	13.9	2.03	-0.86 to 4.92	0.123
	SD	2.13	2.01			
Thickness	N	120	120			
	Mean (mm.)	12.2	11.9	-2.48	-5.66 to 0.70	0.096
	SD	1.45	1.22			

Table 4 Mean alveolar bone height and bone thickness of without and with titanium grade 5 placements.

Alveolar bone measurement		Without titanium	Titanium grade 5	Mean percent difference	95% CI	*p*-value (t-test)
Height	N	120	120			
	Mean (mm.)	13.7	13.9	+1.52	- 0.37 to 3.41	0.089
	SD	2.13	2.15			
Thickness	N	120	120			
	Mean (mm.)	12.2	12.0	-1.41	-2.73 to - 0.08	0.042*
	SD	1.45	1.41			

Table 5 Mean alveolar bone height and bone thickness after titanium grade 4 and grade 5 placements.

Alveolar bone measurement		Titanium grade 4	Titanium grade 5	Mean percent difference	95% CI	*p*-value (t-test)
Height	N	120	120			
	Mean (mm.)	13.9	13.9	+0.51	-1.13 to 2.14	0.440
	SD	2.01	2.15			
Thickness	N	120	120			
	Mean (mm.)	11.9	12.0	-1.07	-3.30 to 1.15	0.252
	SD	1.22	1.41			

Table 6 Mean percent difference of gray values and 95 % CI of mean percent difference of gray values around the implant surface at different aspects after titanium grade 4 and titanium grade 5 placements.

Site	Titanium grade 4			Titanium grade 5		
	Mean percent difference	95% CI	P-value	Mean percent difference	95% CI	*p*-value
Radius 0.5 mm.						
Mesial	-203.1	-274.5 to -131.8	0.007*	-246.1	-369.2 to -123.1	0.007*
Lingual	+107.8	64.9 to 150.7		+74.1	-21.3 to 169.5	
Distal	-237.7	-403.0 to -72.3		-238.3	-342.9 to -133.8	
Buccal	+76.5	5.94 to 147.1		+167.1	96.8 to 237.3	
Radius 1 mm.						
Mesial	-425.6	-861.3 to 10.2	0.165	-209.5	-310.3 to -108.6	0.048*
Lingual	+61.1	24.9 to 97.4		+74.0	35.1 to 112.9	
Distal	-295.7	-570.7 to -20.7		-128.8	-211.0 to -46.6	
Buccal	+0.24	-211.2 to 211.7		+126.3	-7.0 to 259.6	
Radius 2 mm.						
Mesial	-213.1	-325.3 to -101.0	0.121	-124.3	-234.7 to -13.9	0.035*
Lingual	-174.6	-363.8 to 14.5		-500.7	-1259.3 to 257.9	
Distal	-156.3	-234.6 to -77.9		-288.0	-636.1 to 60.1	
Buccal	-66.8	-171.3 to 37.7		+42.7	19.2 to 66.3	

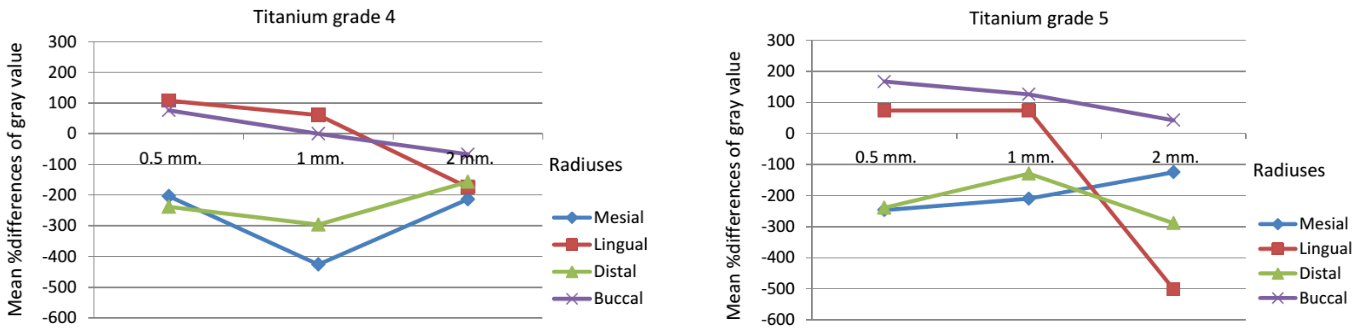

Figure 5 Mean percent difference of gray values around the implant site at radius of 0.5 mm, 1 mm, and 2 mm from implant surface

DISCUSSION

This experimental procedure simulated the clinical procedure of implant placement using the real shape of implant and human mandibles, the results can be inferred to the clinical situation. For the alveolar bone measurements, both of the titanium grade 4 and titanium grade 5 produced an increase in bone height and a reduction of bone thickness after the second implant placement. Titanium grade 4 produced an increase of 2.03 % in bone height and a reduction of 2.48% in bone thickness with no significant difference. Titanium grade 5 produced an increase of 1.52% in bone height and a reduction of 1.41% in bone thickness with significant difference in bone thickness measurement after the second implant placement. The results showed that titanium grade 4 produced more increase in bone height and more reduction in bone thickness than titanium grade 5. However, no significant difference was detected when comparing the measurements taken with titanium grade 4 and titanium grade 5 placements for both parameters. The difference of diameter between titanium grade 4 and titanium grade 5 might cause the different results in each measurement. With the limitation of this study, we could not provide the same diameter of two types of titanium implant. The wider diameter of titanium grade 5 showed the statistically significant difference in bone thickness measurements while the titanium grade 4 did not show the statistically significant difference in bone thickness when comparing taken with and without titanium implant placement. Cremonini et al.[12] examined the artifacts of nickel-chromium metallic restoration on CBCT images. When nickel-chromium metallic restoration was positioned over alveolar ridge adjacent to the mental foramen region, they found that the nickel-chromium restorations produced a reduction of 0.68% in bone height and an increase of 6.12% in bone thickness on CBCT images. No significant difference was demonstrated when comparing measurements performed with and without nickel-chromium metallic restoration. Their findings differed from those of present study. The differences between studies were the metal material and metal position. In 2012, Boas FE, & Fleischmann[8] have reported that metal artifacts on CT image were particularly pronounced with high atomic number metals such as iron or platinum, and less pronounced with low atomic number metals such as titanium. With a higher atomic number of nickel-chromium from Cremonini et al study[12], it may produce more errors than titanium and alloy titanium in alveolar bone measurements on CBCT image. As same as the metal position, Cremonini et al[12] study placed the nickel-chromium over alveolar ridge which could produce the artifacts more than titanium which was placed into alveolar bone in the present study.

For the pretreatment considerations and pretreatment evaluations of single tooth implants, Shah and Lum[13] in 2008 have recommended that the implant should be at least 1.5 mm away from the adjacent teeth and should be at least 3 mm away from an adjacent implant. The minimum available bone width should be such that more than 1 mm of bone should be present on either side of the implant buccolingually to keep the soft tissue levels stable. This indicated that thin layer of bone thickness can effect to the success of implant treatment. Although the titanium grade 4 and grade 5 produced the differences in bone thickness and bone height measurements only about 1.5% to 2.5% on CBCT image, this should be considered in the pretreatment evaluation of single tooth implant treatment when measuring the bone thickness and bone height.

Regarding to the gray value measurements, the result of this study showed that both of the titanium grade 4 and titanium grade 5 produced the increased gray values at buccal and lingual aspects around the implant sites while the reduced gray values was observed at mesial and distal aspects around the implant sites. This result had an agreement with the result of Benic et al[14] study in 2013. They assessed the artifacts induced by titanium dental implants on CBCT images. When 4.1 mm diameter titanium implant was place into the stone models of human mandible at several single-tooth gaps position and the gray values were recorded at eight circumferential positions around the implant at 0.5 mm, 1 mm and 2 mm from the implant surface, they found that increased gray value were found at buccal and lingual aspects, whereas the region of reduced gray values was located mesially and distally at molar, premolar and canine sites and at the mesio-buccal, disto-buccal, disto-buccal and disto-lingual of the incisor sites. In the other words, the regions of reduced gray values were located along the long axis of the mandibular body. This study also has an agreement with the result of Sancho-Puchades[15] study in 2014. When different implant materials-titanium 4.1 mm diameter, titanium 3.3 mm diameter, titanium–zirconium (TiZr) 3.3 mm diameter and zirconium dioxide (ZrO2) 3.5–4.5 mm diameter implants were place into the stone models of human mandible at single-tooth gaps lower left second premolar position and the gray values were recorded with the same procedure of Benic et al study, they found that all types of implant material showed positive gray values buccally, mesio-buccally, lingually and disto-lingually, while the negative gray values were detected mesially and distally. Their result showed that ZrO2 implants caused the most pronounced artifacts in CBCT, followed by TiZr and Ti implants. The intensity of the artifacts around ZrO2 implants in CBCT exhibited in average the threefold in comparison to Ti implants. This indicated that different implant material produced different change of gray value measurements.

In this present study, the mean percent difference of gray value at 4 aspects around the titanium grade 4 showed the significant difference at 0.5 mm from implant surface while the titanium grade 5 showed the significant differences at 0.5 mm, 1 mm, and 2 mm from implant surface. As the different compositions between two grades of the titanium, titanium grade 5 which was added 6% of aluminum and 4% of vanadium can provide the farther artifacts than titanium grade 4. In the other hand, the wider diameter of titanium grade 5 also provided the farther artifacts than titanium grade 4. These led to the significant differences of gray values at 4 aspects around the titanium grade 5 at 0.5 mm, 1 mm, and 2 mm from the implant surface.

Previous studies have indicated the CBCT gray values have a reliability in bone density assessment.[7,16] Emadi et al[16] in 2014 reported that the mean gray value of cortical bone was 1766 with the range of 1,470 to 2,134 and the spongy bone was 541 with the range of 366 to 745. However, the gray values from CBCT images were influenced by device and scanning settings.[17] Thus, to assess the bone density at circumferential position 2 mm around the two types of titanium implant, an examiner should consider the artifacts which produced the increased gray values at buccal and lingual aspects and the reduced gray values at mesial and distal aspect. Nevertheless, without clinical symptoms or certain postoperative complication, there is no indication for follow-up imaging of dental implant by means of CBCT because it provides the higher radiation burden when comparing with the two-dimensional radiography.[18]

Some limitations of this study should be considered such as the gap between implant surface and alveolar socket including the soft tissues, facial muscles and skin which were not presented on dry human mandibles. Further studies should be performed with the complete component of implant. Prosthetic crowns should be fixed to the dental implants in the experiment.

CONCLUSION

Under the condition of this study, the present of two types of titanium implant hardly produced an increase in bone height and a reduction in bone thickness on CBCT images which significantly affect the implant placement in clinical practice. There was no significant difference between titanium grad 4 and titanium grade 5 for both parameters. The artifact around the two types of titanium produced the increased gray values on buccal and lingual aspects while the reduced gray values seen on mesial and distal aspects of implant sites. Although this study showed no clinically significant difference, dentist should be concerned of adjacent bone quality and quantity, when reading CBCT, before the next second implant placement.

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