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Original

Influence of metal artifacts on *in vivo* micro-CT for orthodontic mini-implants

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Abstract: This study aimed to show the effects of metal artifacts on the *in vivo* micro-CT of mini-implants by measuring bone volume. We drilled a hole in the cortical bone of a rat tibia and embedded a titanium orthodontic mini-implant (diameter, 1.5 mm) in the hole. Twelve individually weighed hydroxyapatite grains (HA grains) were placed around the implant either by one dentist (method 1) or separately by 12 dentists (method 2). *In vivo* micro-CT was used to scan the model after placement of each grain to measure increases and decreases in bone volume voxel number. The subtracted bone voxel volume increased with HA weight in both methods. Simple linear regression analysis showed a significant correlation between weight and volume in both methods (method 1: regression coefficient: 516.502, $P < 0.05$; method 2: regression coefficient: 4837.432, $P < 0.05$). Metal artifacts did not appear to influence measurements of bone volume, although further studies are required to determine the effect of thicker implants. (J Oral Sci 54, 55-59, 2012)

Keywords: metal artifact; *in vivo* micro-CT; orthodontic mini-implant.

Introduction

Cone-beam computed tomography has been used to study orthodontic mini-implants and anchoring screws (1-6) and to provide measurements such as bone thickness, bone density, and bone volume. Micro-CT has been used for fundamental studies in several dental fields; however, the recent development of *in vivo* micro-CT (7) enables living subjects to be investigated. Although such *in vivo* studies have been conducted on experimental animals such as rats (8), the effects of metal artifacts have not been investigated.

If metal artifacts influence the bone around the mini-implant anchor, then the implant material has an important effect on errors in measuring bone thickness and volume. This study therefore examined the effect of metal artifacts on a mini-implant. Specifically, we assessed whether there was a detectable effect on measurements of bone volume by *in vivo* micro-CT.

Materials and Methods

In vivo micro-CT

We used *in vivo* micro-CT (R_mCT, Rigaku Co., Tokyo, Japan) for archiving image data (Fig. 1). The

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Fig. 1 A view of the *in vivo* micro-CT device.

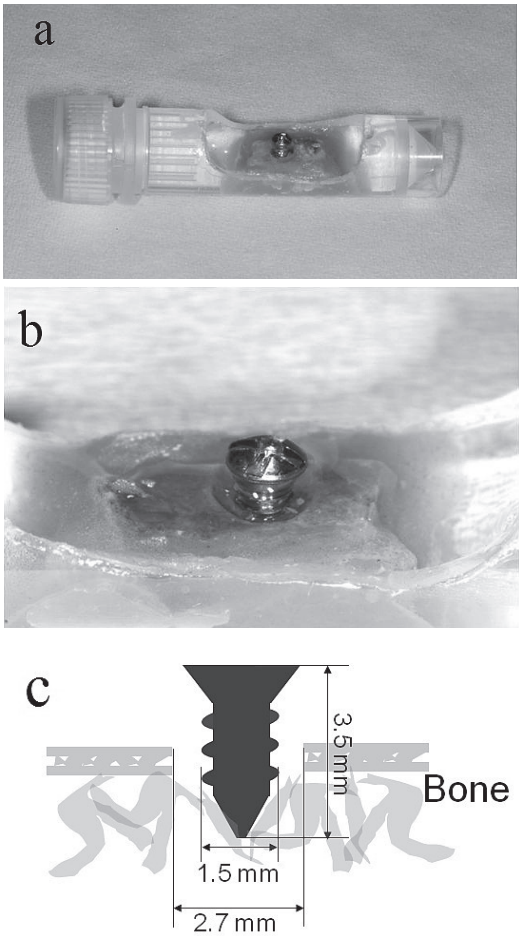


Fig. 2 The tibia was fixed to a sample holder containing the mini-implant. (a) The tibia was fixed to a sample holder, (b) Mini-implant in tibia, (c) A diagram showing the mini-implant with a tibia.

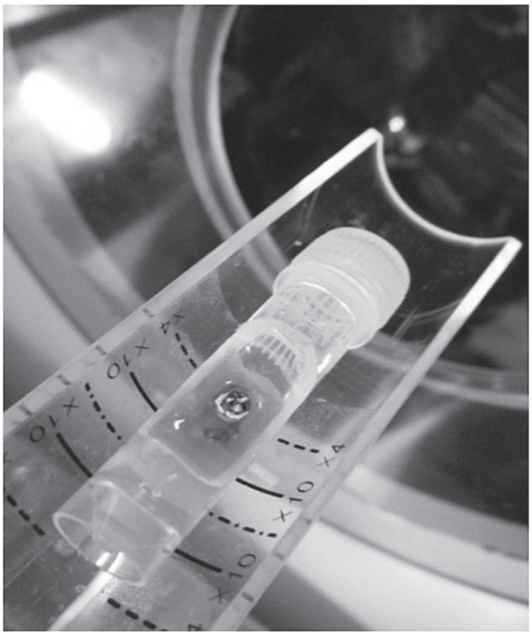


Fig. 3 The plastic holder with the sample was placed on the object stage of the *in vivo* micro-CT device.

microfocus X-ray tube had a minimum spot size of 7 μm. The voxel size was set at 30 × 30 × 30 μm, and scanning time was 2 min. The *in vivo* micro-CT operated at 90 kV and 150 μA. Projection data for a total of 512 frames were collected and reconstructed on I-View-R (J. Morita Mfg. Corp., Kyoto, Japan).

Sample model procedure

First, we prepared a sample consisting of a rat tibia containing a titanium mini-implant (Keisei Medical Industrial Co. Ltd., Tokyo, Japan). A hole 2.7 mm in diameter was drilled in the tibia, into which a 1.5-mm-diameter implant was embedded. Sufficient space was left around the implant for the addition of hydroxyapatite (HA) grains. The tibia was fixed in the plastic sample holder with acrylic resin, and water was added to the plastic sample holder to maintain tibia wetness (Fig. 2a–c).

Study protocol

The plastic holder containing the sample was placed on the object stage of the *in vivo* micro-CT device (Fig. 3), and 12 HA grains (Apaceram-AX; HOYA Co., Tokyo, Japan) were added to the space around the mini-implant.

To inspect the effect of HA distribution, the HA grains were added in two ways. In the first method, an experimenter weighed each HA grain, and the HA grains were then placed around the mini-implant, one at a time, by a single dentist (method 1). In the second method, an experimenter weighed each HA grain, and 12 dentists placed one grain each around the mini-implant (method 2). In both methods, we scanned the model with *in vivo* micro-CT every time a grain was added (Fig. 4a–c). All volume image data were saved to a hard disk drive.

To determine the correlation coefficient between the weight of the HA grain and HA grain bone volume (bone volume numbers), we used BV-measuring software (Kitasenju Radist Dental Clinic, i-View Image Center, Tokyo, Japan) to calculate bone volume from the voxel measuring volume area (3 × 3 × 2 mm) (Fig. 5). We calculated number of voxels by subtracting voxel decrease from voxel increase, which yielded the bone volume voxel number (Fig. 6). We used automatic-alignment software to match the position of each data point.

Simple linear regression analysis was used to determine the correlation coefficient between HA weight and bone volume voxel number. The analysis was performed using SPSS for Windows (SPSS, Chicago, IL, USA).

Results

Table 1 lists HA weights and decreased, increased, and subtracted bone voxel volumes. The increased bone volume voxel numbers ranged from 17,905 to 81,759 for method 1, and from 27,866 to 78,277 for method 2. The subtracted bone volume voxel numbers ranged from 6,529 to 72,121 for method 1, and from 10,723 to 61,446 for method 2. The HA weight difference ranged from 0.08 to 0.18 in method 1 and from 0.06 to 0.22 in method 2.

The value for subtracted bone voxel volume also increased with HA weight in both methods (Figs. 7a and b). In simple linear regression analysis, a significant correlation was observed between weight and volume for both methods (method 1: regression coefficient: 516.502, $P < 0.05$; method 2: regression coefficient: 4837.432, $P < 0.05$).

Discussion

We used *in vivo* micro-CT to evaluate the effect of metal artifacts on measurement of bone volume. In both

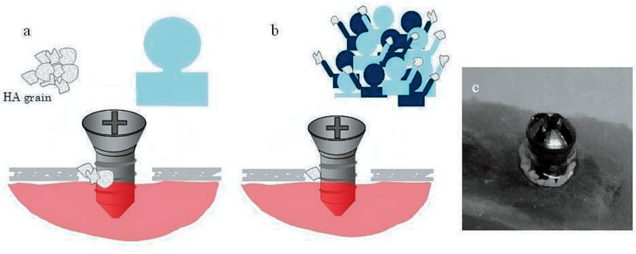


Fig. 4 Placement of 12 HA grains around the mini-implant using (a) method 1 (single dentist) and (b) method 2 (12 dentists). (c) HA grains in the space around the mini-implant.

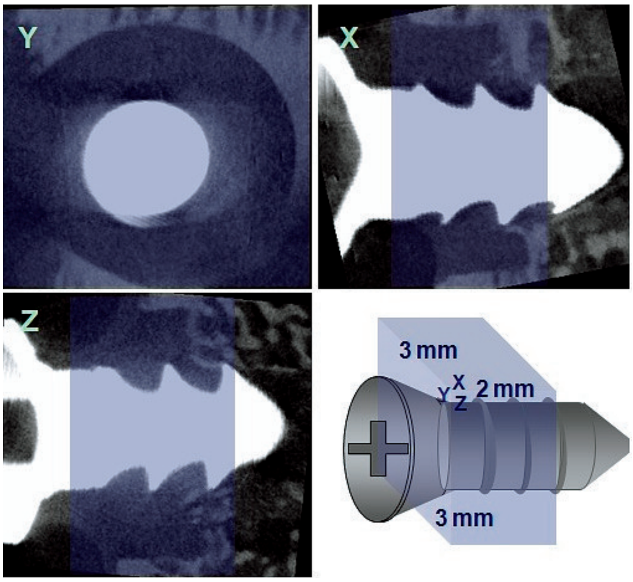


Fig. 5 Establishing the measurement area using BV-measuring software. Bone volume was determined by measuring the volume in areas (shown in blue) from XYZ voxel images.

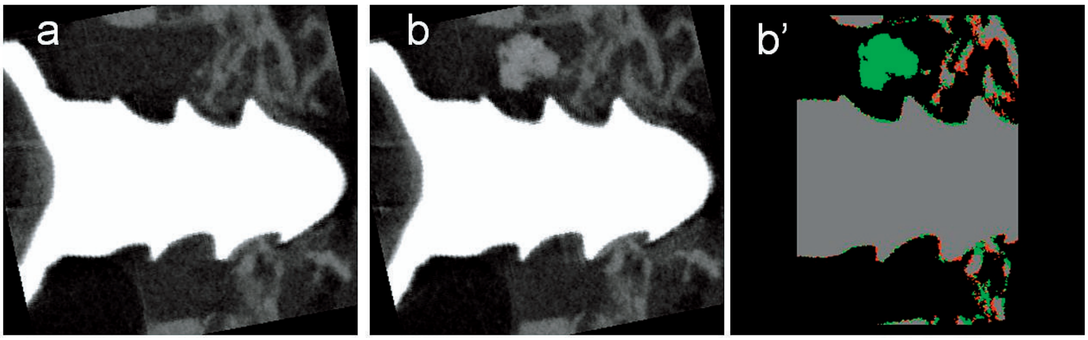
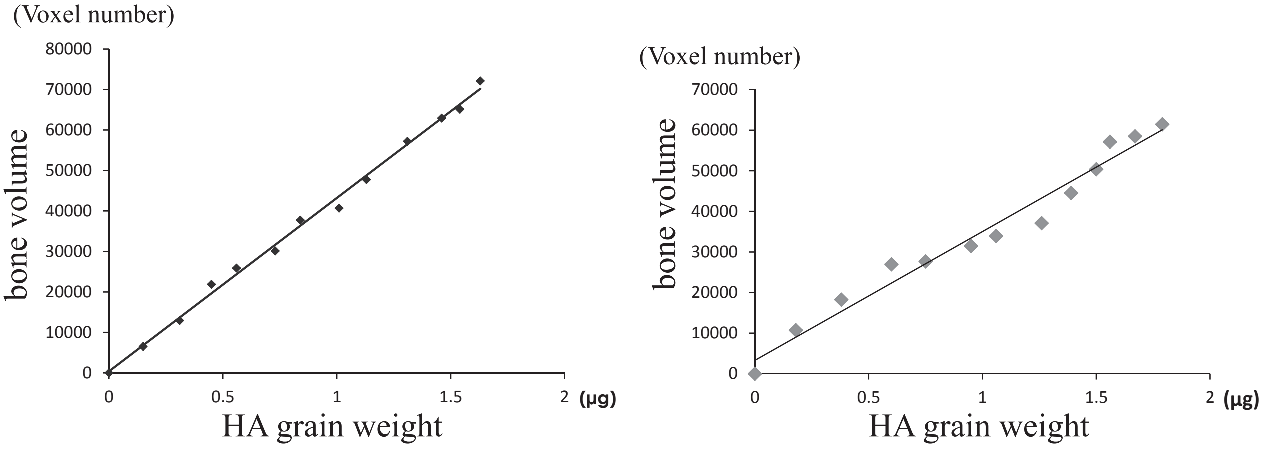


Fig. 6 Subtracting a voxel image without an HA grain from a voxel image with an HA grain (a, b). Green represents increased volume, red shows reduced volume, and gray shows no change (b’).

Table 1 HA weight and bone volume voxel numbers

	Method 1				Method 2			
N	HA grain cumulative weight(μg)	Bone Volume Voxel numbers			HA grain cumulative weight (μg)	Bone volume voxel numbers		
		Decrease	Increase	Subtraction		Decrease	Increase	Subtraction
0	0	0	0	0	0	0	0	0
1	0.15	11376	17905	6529	0.18	17143	27866	10723
2	0.31	12176	25123	12947	0.38	18788	37034	18246
3	0.45	11071	32968	21897	0.6	16387	43342	26955
4	0.56	11991	37898	25907	0.75	21238	48905	27667
5	0.73	11359	41488	30129	0.95	17773	49238	31465
6	0.84	11541	49278	37737	1.06	20678	54603	33925
7	1.01	9642	50357	40715	1.26	22663	59771	37108
8	1.13	10694	58427	47733	1.39	20133	64663	44530
9	1.13	10764	67975	57211	1.5	19250	69635	50385
10	1.46	9304	72229	62925	1.56	21294	78444	57150
11	1.54	10521	75635	65114	1.67	15433	73914	58481
12	1.63	9638	81759	72121	1.79	16831	78277	61446



Regression coefficient = 516.502, slope = 42694.87, $r^2 = 0.995$, $P < 0.05$ Regression coefficient = 4837.432, slope = 30560.11, $r^2 = 0.962$, $P < 0.0$

Fig. 7 Relationship between bone volume (y-axis, number of voxels) and HA grain weight (x-axis, μg). (a) method 1, (b) method 2.

methods 1 and 2, bone volume voxel number was positively associated with weight of HA grains.

Bone volume voxel number did not perfectly fit the regression line because grains sometimes overlapped in the space around the implant, rather than being placed side-by-side. This overlap resulted in misalignment and the weight was different even though the size was identical.

Our findings indicate that errors are due to human factors and HA grain characteristics, not to the metal artifacts. Indeed, most orthodontic mini-implants are made from titanium, which is reported to have little effect on CT imaging (9,10). Therefore, we believe that the mini-implant material will not affect measurement of bone volume if *in vivo* micro-CT is conducted in the manner described in this study.

Our mini-implants were 1.5 mm in diameter; however, if the diameter were larger, it is possible that the metal artifact would surround the implant and affect the findings. Moreover, the slope of the regression line differed in graphs of methods 1 and 2. The difference represented an approximately 10% absolute error, and bone volume numbers measured on an implant of different size and under different scan conditions would reflect this difference. It is therefore important to conduct additional studies with implants of larger diameters to evaluate the effect of thicker metal artifacts on bone volume. The bone burr and bone dust must also be sufficiently removed from the mini-implant to ensure the accuracy of bone volume measurements.

Acknowledgments

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References

1. Kim SH, Choi YS, Hwang EH, Chung KR, Kook YA, Nelson G (2007) Surgical positioning of orthodontic mini-implants with guides fabricated on models replicated with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 131, S82-89.
2. Kim GT, Kim SH, Choi YS, Park YJ, Chung KR, Suk KE, Choo H, Huang JC (2009) Cone-beam computed tomography evaluation of orthodontic miniplate anchoring screws in the posterior maxilla. Am J Orthod Dentofacial Orthop 136, 628.e1-10.
3. Leea NK, Baek SH (2010) Effects of the diameter and shape of orthodontic mini-implants on microdamage to the cortical bone. Am J Orthod Dentofacial Orthop 138, 8.e1-8.
4. Lemieux G, Hart A, Cheretakis C, Goodmurphy C, Trexler S, McGary C, Retrouvey JM (2011) Computed tomographic characterization of mini-implant placement pattern and maximum anchorage force in human cadavers. Am J Orthod Dentofacial Orthop 140, 356-365.
5. Wilmes B, Drescher D (2011) Impact of bone quality, implant type, and implantation site preparation on insertion torques of mini-implants used for orthodontic anchorage. Int J Oral Maxillofac Surg 40, 697-703.
6. Zhang Q, Zhao L, Wu Y, Wang H, Zhao Z, Xu Z, Wei X, Tang T (2011) The effect of varying healing times on orthodontic mini-implant stability: a microscopic computerized tomographic and biomechanical analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 112, 423-429.
7. Arai Y, Ninomiya T, Tanimoto H (2007) Development of in vivo micro computed tomography using flat panel detector. Dent Jpn 43, 109-111.
8. Kochi G, Sato S, Fukuyama T, Morita C, Honda K, Arai Y, Ito K (2009) Analysis on the guided bone augmentation in the rat calvarium using a microfocus computerized tomography analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 107, e42-48.
9. von Holst H, Bergström M, Möller A, Steiner L, Ribbe T (1977) Titanium clips in neurosurgery for elimination of artefacts in computer tomography (CT): a technical note. Acta Neurochir (Wien) 38, 101-109.
10. Muraru L, Van Lierde C, Naert I, Vander Sloten J, Jaecques SVN (2009) Three-dimensional finite element models based on in vivo microfocus computed tomography: elimination of metal artefacts in a small laboratory animal model by registration with artefact-free reference images. Adv Eng Software 40, 1207-1210.