Comparison of GSV of CBCT with HU of MDCT in different restorative materials

Abstract

Densitometry plays an important role in diagnosis and treatment planning in today's world. This study aimed to compare the grayscale value (GSV) of cone beam computed tomography(CBCT) with Hounsfield unit (HU) of computed tomography (CT) for five commonly used restorative materials including amalgam, composite resin, flowable composite, glass ionomer (GI), and calcium hydroxide. This study aims to solve problems related to the misdiagnosis of restorative materials and take a step forward for the simulation of these two parameters(HU, GSV) for the reconstruction of CT images from CBCT imaging data.
Seven specimens from seven different brands of amalgam, composite resin, and flowable composite (n=1 from each brand) and five specimens from five brands of GI and calcium hydroxide(n=1 from each brand) were fabricated with a 5 mm^3 dimension. Cubic wooden molds measuring 5 x 5 x 5 mm were used for this purpose. The specimens underwent CBCT and MDCT under standard exposure conditions, and the GSV and HU were calculated and compared. The maximum GSV, maximum, minimum, and mean HU of amalgam were significantly higher than other materials ($P<0.05$). Linear regression analysis showed a significant linear correlation between the GSV and HU of restorative materials when assessing their maximum and mean values ($P=0.001$). CBCT and CT can help in the differentiation of amalgam from other restorative materials. Also, the HU can be calculated according to the mean or maximum GSV of a material.

Keywords: *Computed tomography, Cone Beam Computed Tomography, Densitometry, Dental materials*

Ava Nikbin[1*] , Fatemeh ghezi[2] , Raheb Ghorbani[3]

1- *Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Semnan University of Medical Sciences, Semnan, Iran,* nikbinava@yahoo.com

2- *Dentist, Faculty of Dentistry, Semnan University of Medical Sciences, Semnan, Iran,* fatemeghezi98@gmail.com

3- *Department of social medicine, Faculty of Medicine, Semnan university of medical sciences, Semnan, Iran,* ghorbani_raheb@yahoo.com

**corresponding author:* nikbinava@yahoo.com

Introduction

Densitometry plays an important role in diagnosis and treatment planning in today's world. Depending on the atomic number and density, equal amounts of different materials absorb different levels of the X-ray beam and yield a different radiographic view even on plain films (1). Thus, knowledge about the density of different materials can enhance their identification.

The currently available dental materials have adequate radiopacity to be differentiated from the enamel and dentin on dental radiographs. This property can be of help in the radiographic assessment of restorations, root fillings, marginal defects, restoration contour, and detection of secondary caries and restoration defects (2).

Computed tomography (CT) and cone-beam computed tomography (CBCT) are valuable supplemental imaging modalities in diagnosis and have several clinical applications (3). Both of the above-mentioned modalities have units for the assessment of the density of different materials(4). CT images are recorded and displayed through a matrix of separate blocks called voxels. Each square of the image matrix is one pixel (5). For image display, each pixel is characterized with a number, which indicates the rate of X-ray attenuation by the respective tissue and is called the Hounsfield unit (HU). The HU is used for the assessment of material and tissue density and serves as the gold standard for the assessment of tissue density (6).

CBCT is a novel modality for scanning and volumetric data reconstruction and is extensively used to obtain 3D and multiplanar images (1).

Bit depth refers to the ability of CBCT to reveal the differences in beam attenuation, and determines the available grayscale value (GSV) for image visualization. GSV is used for the assessment of the density of different materials on CBCT scans. CBCT provides accurate images on a submillimeter scale with a shorter scanning time, lower patient radiation dose, and lower cost compared with medical CT. However, beam hardening artifacts, higher scattering radiation, and the absence of true HU are among the shortcomings of CBCT, compared with CT. Nonetheless, recent evidence suggests that the CBCT GSV can be used to calculate the HU and subsequently the density of different materials/tissues (7,8).

Studies on the density of restorative materials by using CBCT, in comparison with CT, are limited (3). Thus, this study aimed to compare the HU and GSV of multi-detector CT (MDCT) with GSV of CBCT for five commonly used restorative materials to solve problems related to misdiagnosis of restorative materials and linkage of HU and GSV for the reconstruction of CT and CBCT images.

Materials and Methods

This in vitro, the experimental study evaluated five dental restorative materials namely composite resin, amalgam, flowable composite, glass ionomer (GI), and calcium hydroxide, each from seven different manufacturers, except for GI and calcium hydroxide, for which, the products of five different manufacturers were evaluated. The selection of material brands was based on their availability and having FDA approval. The materials were applied in cubic wooden molds measuring 5 x 5 x 5 mm as used in the clinical setting, and allowed to reach their final setting.

Amalgam brands include: A – ANA 2000® (Nordiska Dental, Ängelholm, Sweden); B – Cinalux® (Shahid Faghihi, Tehran, Iran);C – GK-110® (AT&M Biomaterials, Beijing, China); D_ Dibaloy® (Trent Dent, London, UK);E – GS-80® (SDI, Victoria, Australia); F – Solaloy® (Trent Dent , London, UK);G – MN-80® (Sepehr, Tehran,Iran);

Composite resin brands include: A – Filtek Z250-XT® (3M, Seefeld, Germany);B – Filtek P60® (3M, United States); C – Denfil® (Vericom, Anyang, South Korea); D – Gradia®Direct (GC,America); E – Filtek Z350-XT® (3M, Seefeld, Germany);F – Estelite Sigma Quick® (Tokuyama, Tokyo, Japan); G – Amelogen®Plus (Ultra Dent, South Jordan);

Flowable composite resin include:A – Diafil Flow® (Diadent, Cheongju,South Korea);B – Denfil Flow® (Vericom, Anyang, South korea); C – Tetric EvoFlow ® (Ivocar VivaDent, Suitzerland);D – Gradia Direct Flow® (GC, America);E – Opallis Flow® (FGM, Joinville,Brazil);F – Estelite Sigma Quick Flow® (Tokuyama, Tokyo, Japan); G – FillDent Flow® (Dental World, Italy);

Glass inomer brands include: A – GC Fuji I® (GC, Tokyo, Japan);B – Ionoseal® (VOCO, Cuxhaven, Germany); C – Zirconomer® (Shofu, United Kingdom);D – CoreShade® (Shofu, United Kingdom);E – GC Gold label type 2 ® (GC,Tokyo, Japan);

And calcium hydroxide brands include: A – Lime-Lite Cavity liner® (Pulpdent Corporation, Watertown, USA); B – Dycal Ivory® (Dentsply,Tulsa, USA);C_ Master-Dent Cavity Liner® (Dentonics, North Carolina, USA);D – Hidrox-Cal® (Maquira, Maringá, Brazil);
E – Charm Base® (Dent Kist, South Korea)

Amalgam was well condensed with a condenser, and composite resins were applied incrementally and light-cured. Flowable composite, GI, and Dycal were also light-cured. After the final set, the specimens were removed from the wooden molds, and each group's specimens were placed on cardboard at an adequate distance from each other (Figure 1). Composite resin, flowable composite, GI, and calcium hydroxide specimens were placed on 4 separate cardboards at a 1.5 cm distance from each other. This distance for amalgam restorations was slightly greater than that for other specimens (approximately 2 cm) due to the artifacts caused by amalgam during imaging. We had some limitations regarding the length and width of the cardboard since a larger size would exceed the field of view of CBCT. Thus, for amalgam specimens, due to their greater distance from each other, one of the specimens had to be scanned separately.

Each cardboard with one type of restorative material was separately scanned by a CBCT scanner (Planmeca, Helsinki, Finland) under standard exposure settings of 50 x 50 mm field of view, 80 kVp, 12 mA, and also by an MDCT scanner (Alexion, Toshiba, Tokyo, Japan) under standard exposure conditions of 120 kVp, 12 mA, and 50 x 50 mm field of view

All images were evaluated in the coronal and axial planes using Romaxis (Planmeca, Helsinki, Finland) and Syngo FastView (AG; Siemens, Munich, Germany)software by an experienced oral and maxillofacial radiologist. (figure 2,3) The GSV and HUs were calculated and compared. Finally, based on the type of restorative material that underwent scanning, a range of HUs and GSVs were calculated for each material and compared.

In this study, the Shapirovilk test was used to evaluate the normality of the data and Kruskal Wallis tests (or one-way analysis of variance) and linear regression to find the relationship between the data. The software used was SPSS 24.0 and the significance level was 0.05.

Results

This study evaluated 7 brands of amalgam, composite resin, and flowable composite, and 5 brands of GI and Dycal regarding their GSV and HU.

- Grayscale value

The results of table 1 show that no significant difference in the minimum GSV of different restorative materials (P=0.109). However, the maximum GSV of restorative materials was significantly different (P=0.004) such that the maximum GSV of amalgam was significantly higher than that of GI (P=0.002), composite resin (P=0.001), calcium hydroxide (P=0.003), and flowable composite (P=0.012). (Table 1,)

- Hounsfield unit

The minimum HU is significantly different among different restorative materials (P=0.001, Table 2) such that the minimum HU of amalgam was significantly higher than that of GI (P<0.001), composite resin (P=0.001), calcium hydroxide(P=0.003), and flowable composite (P=0.012). Other groups had no significant difference (P>0.05).

The maximum HU was significantly different among different groups (P=0.002, Table 2) such that the maximum HU in the amalgam group was significantly higher than that in GI (P=0.002), composite resin (P<0.001), calcium hydroxide (P=0.003), and flowable composite (P=0.008) groups. Other groups had no significant difference (P>0.05).

The mean HU of different groups was also significantly different (P=0.002) such that the mean HU of amalgam was significantly higher than that of GI (P=0.001), composite resin (P=0.001), calcium hydroxide (P=0.003), and flowable composite (P=0.008). Other groups had no significant difference (P>0.05).

Assessment of minimum, maximum, and mean HU of different groups showed that the HU of amalgam was significantly higher than that of other groups (P<0.05).

In the assessment of different brands of the same restorative material, the results were reported descriptively since only one specimen of each brand was evaluated (Table 3).

Among composite resins, the highest minimum, maximum, and mean HUs and the highest maximum and mean GSVs were recorded in Amelogen Plus. Also, the highest minimum GSV belonged to Denfil. The lowest minimum, maximum, and mean HU and GSV belonged to Gradia Direct.

Among flowable composites, the highest minimum, maximum, and mean HU and GSV belonged to Tetric EvoFlow, and the lowest minimum, maximum, and mean HU and GSV belonged to Estelite Sigma Quick.

Among amalgams, the highest minimum and mean HU, and minimum, maximum, and mean GSV belonged to MN-80. Also, the maximum HU was recorded in ANA2000. The lowest minimum, maximum, and mean HU, and minimum and mean GSV belonged to Cinalux. The lowest maximum GSV belonged to GS-80.

Among GIs, the highest minimum, maximum, and mean HU, and minimum GSV belonged to GC Gold Label 2. Also, the highest maximum and mean GSV belonged to GC Gold Label 22. The lowest minimum, maximum, and mean HU and GSV belonged to Zirconomer.

Among calcium hydroxides, the highest minimum, maximum, and mean HU and maximum and mean GSV belonged to Charm Base. The highest minimum GSV belonged to Ivory Dentsply. The lowest minimum, maximum, and mean HU and maximum and mean GSV belonged to Hidrox-Cal. Also, the lowest minimum GSV belonged to Master Dent.

- Linear regression analysis showed a significant linear correlation between the GSV and HU of the restorative materials in maximum (P<0.001) and mean (P=0.001) values. No significant correlation was found between minimum GSV and HU (P=0.71). (table 4)

Gray scale (mean) = 4608.5 + 0.21 Hounsfield unit (mean)

Gray scale (max) = 4034.5 + 0.39 Hounsfield unit (max)

Discussion

This study aimed to compare the HU of MDCT with GSV of CBCT for five commonly used restorative materials to solve problems related to the misdiagnosis of restorative materials and the linkage of HU and GSV for the reconstruction of CT and CBCT images. The latter took one step forward for segmentation and reconstruction of CBCT to CT images and image data transfer from one imaging modality to the image processing software of the other modality. Thus, by having the CBCT image of an object, its CT image can be reconstructed. The density of the contrast medium, thickness of specimens, and energy of the X-ray beam all affect beam absorption by restorative materials. Thus, in this study, the materials were standardized in terms of thickness by using equal-size molds. The X-ray beam energy was also standardized by adopting the same exposure settings for all specimens.

Emadi et al. (3,14,15) compared the CT number and GSV of several restorative materials using CT and CBCT. Some of the restorative materials evaluated in their study were similar to those in the present study including amalgam, composite resin, GI, and calcium hydroxide they fabricated three specimens from each material; while in the present study, 7 different brands of amalgam, composite resin, and flowable composite and 5 different brands of calcium hydroxide and GI were evaluated. Emadi et al. (3)showed that amalgam and AH-26 had the highest GSV among the studied materials. Zinc phosphate, gutta-percha, and zinc oxide eugenol ranked second, and mineral trioxide aggregate and polycarboxylate ranked next. Their results were in line with the present findings regarding the maximum GSV of amalgam. However, they did not assess the correlation of GSV and HU of scanners, and they mainly focused on the effect of the type of scanner on the obtained GSV and HU.

Hadidi et al. (1) evaluated the gray level of amalgam, composite resin, flowable composite, GI, and calcium hydroxide using CBCT. The restorative materials evaluated in their study were similar to those in the9 present study. They indicated that amalgam had a higher GSV than other restorative materials, and its GSV was comparable to that of composite resin in some cases, indicating that amalgam and composite resin had high GSVs, and GI, calcium hydroxide, and flowable composite had low GSV's. They confirmed that CBCT can efficiently differentiate amalgam and composite resin from other restorative materials such as GI, calcium hydroxide, and flowable composite. Although the present study was similar to that of Hadidi et al, (1) in terms of study groups and comparison of GSVs, the main objective of the present study was to compare the GSV of CBCT and HU of CT for different restorative materials to find a correlation between them and link these two scales, and succeeded to some extent. The present results regarding the maximum GSV of amalgam were in line with those of Hadidi et al (1). Also, the present results demonstrated that the mean and maximum GSV and HU for different dental materials had a linear correlation,

and the data from each modality can be converted to the other by the processing software.

Lachowski et al. (9)evaluated the radiopacity of different dental materials (base and liners) using an intraoral digital X-ray unit (RVG:5000 Kodak) at 30 cm distance with 70 kVp, 7 mA, and 32.0 seconds. They also evaluated Ionoseal GI, Tetric-Flow and Opallis Flow flowable composites, and calcium hydroxide (Hydrox C). They reported the maximum GSV of Riva self-cure GI for specimens with 1 mm thickness, Surefil flowable composite for specimens with 2 mm thickness, and Tetric Flow flowable composite for specimens with 3 mm thickness. The minimum GSV was recorded for Ionomaster GI in all three thicknesses. They also compared the radiopacity of different restorative materials with enamel and dentin and reported that Riva self-cure and Tetric-Flow had an opacity greater than that of enamel, and masked dental caries on radiographs; therefore, they are not suitable for clinical applications. Tetric-Flow flowable composite was also used in the present study. In 3 mm thickness, it had maximum GSV in the study by Lachowski et al (9). In the present study, it ranked second in terms of GSV, which was in line with the results of Lachowski et al (9). It should be noted that the high GSV of a material has a direct correlation with its density, which explains the present findings regarding the lowest GSV recorded for a flowable composite with maximum flowability because flowability is one of the most important properties of flowable composites. Also, Lachowski et al.(9) scanned specimens with different dimensions and concluded that the thickness of specimens directly affected the imaging outcome. Materials with higher thickness have a higher volume of material constituents. Thus, higher amounts of X-ray beams are absorbed, and less amount is passed. In the present study, the dimensions including the thickness of all specimens were standardized for scanning (all were 5 mm). Moreover, the highest and the lowest HU and GSVs were recorded and evaluated considering the direct correlation of density with HU and GSV of CT and GSV of CBCT.

Imaging with a digital intraoral X-ray unit has a lower cost than CBCT and CT; however, this modality does not provide a numerical value for the radiopacity of the materials. Thus, the opacity of materials in the study by Lachowski et al(9) was compared with the opacity of different thicknesses of aluminum wraps. Aluminum wraps produced by different manufacturers have different compositions, which affects their opacity. Also, a comparison of the opacity of materials with that of aluminum wraps is a relative assessment and does not provide a definite value. However, in the present study, CT and CBCT imaging modalities were used which have higher accuracy and resolution than other imaging modalities. De Souza et al. (10) evaluated the optical density of calcium hydroxide and GI, and reported that the minimum thickness for assessment of radiopacity of different materials should be 1.5 to 2 mm. In the present study, the thickness of each material specimen was 5 mm, which was similar to the study by De Souza et al.(10) although they used intraoral radiography for the assessment of the opacity of dental materials. Scanning conditions and type of scanner can also affect the results of CT and CBCT. Parsa et al.(11) used two different CBCT scanners and one CT scanner to assess the effect of different scanning conditions. They changed the voltage (kVp), amperage (mA), exposure time (seconds), field of view, resolution, rotational arc, and orientation of the specimen relative to the horizontal plane, and concluded that all these parameters had a significant effect on the HU and GSV. The effect of the type of scanner on the final radiopacity value has been the topic of many investigations. Accordingly, Mah et al.(12) evaluated 11 CBCT scanners and 2 CT scanners, Razi et al.(13) evaluated 3 CBCT scanners and 1 CT scanner, and Emadi et al.(3) evaluated 2 CBCT scanners and 1 CT scanner and reported results similar to those of Parsa et al.(11) In the present study, one CBCT scanner (Planmeca) and one MDCT scanner (Alexion) were used to eliminate the confounding effect of type of scanner on the final radio-density. Mah et al.(12) evaluated different structures using 11 dental CBCT and 2 medical CT scanners and found a significantly strong correlation between the HU of CT and GSV of CBCT, which was in agreement with the present results. The present study also found a significant linear correlation between the mean and maximum HU and GSV of CT and CBCT for different restorative materials.

Razi et al.(13) used a sheep head with facial soft tissue and Mah et al.(12) placed the specimens in a water container to simulate beam attenuation by the soft tissue. However, Parsa et al.(11) used a dry mandible without soft tissue. In the present study, the confounding effect of factors such as facial soft tissue, tongue, and saliva was eliminated to obtain a pure value for HU and GSV for restorative materials to pave the way for future studies on this topic.

Conclusion

The present results revealed that the minimum, maximum, and mean HU of amalgam were significantly higher than the corresponding values for other dental restorative materials. Also, the maximum GSV of amalgam was significantly higher than that of other materials, which may be of help in the differentiation of amalgam from composite resin, flowable composite, GI, and calcium hydroxide(16). Also, the main finding of the present study was the significant linear correlation of the HU with the mean and maximum GSV's.

Acknowledgment: The authors would like to express their appreciation to Mahsa Zangane for her assistance with respect to the data collection of the work.

Conflict of interest:

Authors declare no conflicts of interest.

Financial support:

Authors declare no financial support .

Ethics statement:

This is an experimental study and was registered with the code of ethics of IR.SEMUMS.REC.1399.122

References

[1] Hadadi P, Ostovarrad F, Nikbin A, Ranjzad H, Ghasemi F, Nemati S. Evaluation of the gray level of restorative materials using cone-beam computed tomography: A cross-sectional study. Dent Med Probl. 2018;55(3):267-74.DOI 10.17219/dmp/93569

[2] Fonseca RB, Branco CA, Soares PV, Correr-Sobrinho L, Haiter-Neto F, Fernandes-Neto AJ, et al. Radiodensity of base, liner and luting dental materials. Clin Oral Inves. 2006;10(2):114-8. DOI:10.1007/s00784-005-0030-3

[3] Emadi N, Safi Y, Bagheban AA, Asgary S. Comparison of CT-number and grayscale value of different dental materials and hard tissues in CT and CBCT. Iran Endod J. 2014;9(4):283. DOI:10.22037/IEJ.V9I4.5644

[4] Bushong SC. Radiologic science for technologists-E-book: physics, biology, and protection: Elsevier Health Sciences; 2013.

[5] White SC, Pharoah MJ. Oral radiology-E-Book: Principles and interpretation: Elsevier Health Sciences; 2019.

[6] Cassetta M, Stefanelli LV, Pacifici A, Pacifici L, Barbato E. How Accurate Is CBCT in measuring bone density? A comparative CBCT-CT in vitro study. Clin Implant Dent Relat Res. 2014;16(4):471-8. DOI:10.1111/cid.12027

[7] Haristoy R, Valiyaparambil J, Mallya S. Correlation of CBCT gray scale values with bone densities. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;4(107):e28. DOI:10.1016/J.TRIPLEO.2008.12.034

[8] Neugebauer J, Shirani R, Mischkowski RA, Ritter L, Scheer M, Keeve E, Zöller JE. Comparison of cone-beam volumetric imaging and combined plain radiographs for localization of the mandibular canal before removal of impacted lower third molars. 2008 ;105(5):633-42. doi: 10.1016/j.tripleo.2007.08.041.

[9] Lachowski KM, Botta SB, Lascala CA, Matos AB, Sobral MAP. Study of the radio-opacity of base and liner dental materials using a digital radiography system. Dentomaxillofac Radiol. 2013;42(2):20120153. doi: 10.1259/dmfr.20120153.

[10] de Souza FCP, Pardini LC, Cruvinel DR, Hamida HM, Garcia LF. In vitro comparison of the radiopacity of cavity lining materials with human dental structures. J Conserv Dent.. 2010; 13(2):65-70. DOI:10.4103/0972-0707.66713

[11] Parsa A, Ibrahim N, Hassan B, Motroni A, Van der Stelt P, Wismeijer D. Influence of cone beam CT scanning parameters on grey value measurements at an implant site. Dentomaxillofac Radiol. 2013;42(3): 79884780. doi: 10.1259/dmfr/79884780.

[12] Mah P, Reeves T, McDavid W .Deriving Hounsfield units using grey levels in cone beam computed tomography. Dentomaxillofac Radiol. 2010;39(6):323-35. doi: 10.1259/dmfr/19603304.

[13] Razi T, Niknami M, Ghazani FA. Relationship between Hounsfield unit in CT scan and grayscale in CBCT. J Dent Res Dent Clin Dent Prospects. 2014;8(2):107. doi: 10.5681/joddd.2014.019

[14] El Ashiry EA, Alamoudi NM, Farsi NM, Al Tuwirqi AA, Attar MH, Alag HK, Basalim AA, Al Ashiry MK. The Use of Micro-Computed Tomography for Evaluation of Internal Adaptation of Dental Restorative Materials in Primary Molars: An In-Vitro Study. International Journal of Pharmaceutical Research & Allied Sciences. 2019 Jan 1;8(1).

[15] Deepak S, Nivedhitha MS. Proximal contact tightness between two different restorative materials–An in vitro study. Journal of Advanced Pharmacy Education & Research. 2017;7(2).

[16] Alfakhri KH, Aldosari RS, Alturki IB, Alhussain BS. RESIN-BASED SEALANTS VS. GLASS IONOMER SEALANTS: A SYSTEMATIC REVIEW TO DETERMINE THE CLINICAL EFFICACY AND LONGEVITY. Annals of Dental Specialty Vol. 2021 Oct;9(4):1.

Hounsfield unit			Grayscale			material
Max	min	mean	Max	min	mean	composite
6392	6013	6213.6	5592	5224	5405	Filtek Z250
6054	5485	5748.7	5536	5160	5307.3	Filtek P60
10139	9077	9581.1	8824	8119	8470.8	Denfil
578	137	392.6	716	624	668.1	Gradia Direct
5116	4218	4577.8	4958	4470	4694.6	Filtek Z350XT
3931	3440	3799.9	3752	3564	3637.2	Estelite sigma Quick
12784	5960	11665	12007	10351	10882.8	Amelogen Plus
Max	min	mean	Max	min	mean	Composite flow
7689	7147	7425.9	6781	5772	6326.1	Diafil Flow
7409	6605	6991.5	7289	6502	6711.5	Denfil Flow
11385	9966	10526	11410	9449	10305.6	Tetric EvoFlow
4306	3846	4072	4060	3863	3963.4	Gradia Direct
10182	8690	9304.8	8687	8168	8377.5	Opallis Flow
3586	3344	3481.3	3529	3271	3385.6	Estelite sigma Quick
7865	7128	7484	7037	6476	6704.1	FillDent Flow
Max	min	mean	Max	min	mean	amalgam
12308	3564	7518.3	29478	20428	211270.9	ANA2000
13622	2440	5522.8	20035	18736	19355.2	Cinalux
12842	3706	8323.6	20729	2004	20368.2	GK-110
12791	3480	6903	21815	20120	20810.8	Dibaloy
10337	4595	7805.6	21949	20009	20416.8	GS-80
14248	4302	8438.2	22136	20680	21152.7	Solaloy
13224	3803	10558.1	29201	23157	24273.1	MN-80
Max	min	mean	Max	min	mean	Glass inomer
6845	5924	6490.7	6202	4983	5729.5	GC gold label 22
6645	5720	6073.6	5868	3351	5161.8	Lonoseal
2139	1041	1424.5	3383	1245	1730.5	Zirconomer
6289	5887	6146.2	5560	4866	5340.9	Coreshade
6599	6150	6403.3	6381	5629	5827.5	GC gold label 2
Max	min	mean	Max	min	mean	Calcium hydroxide
6595	5756	6347.1	5787	5184	5401.3	Lime-lite cavity linear
5517	4815	5171.2	5554	4627	5243	Dycal Ivory
6407	2343	5522.5	6177	5381	5553.5	Master-Dent cavity Linear
4859	4044	4391.4	4548	3846	4079.9	Hidrox-Cal
8589	4618	7630.3	7454	6183	7015.3	Charm Base

Table 1: mean, minimum, and maximum of Hounsfield Unit and Gray Scale Value of 5 restorative materials (different brands)

P-Value	max	min	CI =95%		STD	mean	count	material	parameter
0.001	10351	624	8259.7	2458	3136.5	5358.8	7	Composite	minimum
	9449	3271	8241.3	4187.5	2191.6	6214.4	7	Composite flow	
	23157	18736	21689.7	19205.7	1343	20447.7	7	amalgam	
	5629	1245	6199.2	1830.4	1759.3	4014.8	5	Glass inomer	
	6183	3846	6126.5	3961.8	871.7	5044.2	5	Calcium hydroxide	

0.002	12007	716	9256.2	2568	3615.8	5912.1	7	Composite	maximum
	11410	3529	9449.5	4491.3	2680.5	6970.4	7	Composite flow	
	29478	20035	27299	19941.8	3977.6	23620.4	7	amalgam	
	6381	3383	6985.2	3972.4	1213.2	5478.8	5	Glass inomer	
	7454	4548	7213.9	4594	1055	5904	5	Calcium hydroxide	
0.002	10882.8	668.1	8631.1	2530.5	3298.1	5580.8	7	Composite	mean
	10305.6	3385.6	8748.7	4329.5	2389.1	6539.1	7	Composite flow	
	24273.1	19355.2	22516.8	19668.2	1540	21092.5	7	amalgam	
	5827.5	1713.5	6886.7	2629.4	1714.3	4758	5	Glass inomer	
	7015.3	4079.9	6758.3	4158.9	1046.8	5458.6	5	Calcium hydroxide	

Table 2: standard deviation and mean of Hounsfield unit in different restorative materials

P-Value	max	min	CI =95%		STD	mean	count	material	parameter
0.109	9077	137	7449.3	2359.3	2751.8	4904.3	7	Composite	minimum
	9966	3344	8890.3	4459.9	2395.2	6675.1	7	Composite flow	
	4595	2440	4333.5	3063.5	686.6	3698.6	7	amalgam	
	6150	1041	7660.5	2228.3	2187.4	4944.4	5	Glass inomer	
	5756	2343	5883.4	2747	1263	4315.2	5	Calcium hydroxide	
0.004	12784	578	10136.5	2718.9	4010.2	6427.7	7	Composite	maximum
	11385	3586	10104.3	4873.4	2827.9	7488.8	7	Composite flow	
	14248	10337	13916.1	11618.8	1242	12767.4	7	amalgam	
	6845	2139	8189.8	3217	2002.5	5703.4	5	Glass inomer	
	8589	4859	8147.8	4639.3	1412.8	6393.6	5	Calcium hydroxide	
	11664.9	392.6	9443.5	2550.2	3726.7	5996.2	7	Composite	mean
	10525.9	3481.3	9401.7	4679.7	2552.9	7040.7	7	Composite flow	

0. 220	105 58.1	55 22.7	929 6.2	643 7.9	15 45.2	786 7	7	amalg am	
	649 0.7	14 24.5	801 1.5	260 3.7	21 77.6	530 7.6	5	Glass inomer	
	763 0.3	43 91.4	734 6.5	427 8.5	12 35.4	581 2.5	5	Calciu m hydroxide	

Table 3: standard deviation and mean of grayscale value in different restorative materials

	β regression coefficient		β index error		P-value
	max	mean	Max	mean	
Hounsfield unit	0.39	0.21	0.04	0.06	0.001
Constant coefficient	559.7	628.5	4034.5	4608.5	<0.001

Table 4: linear regression results, the relation between max and mean Hounsfield unit and grayscale value

Figure1: cubes of cardboard grid filled with dental materials

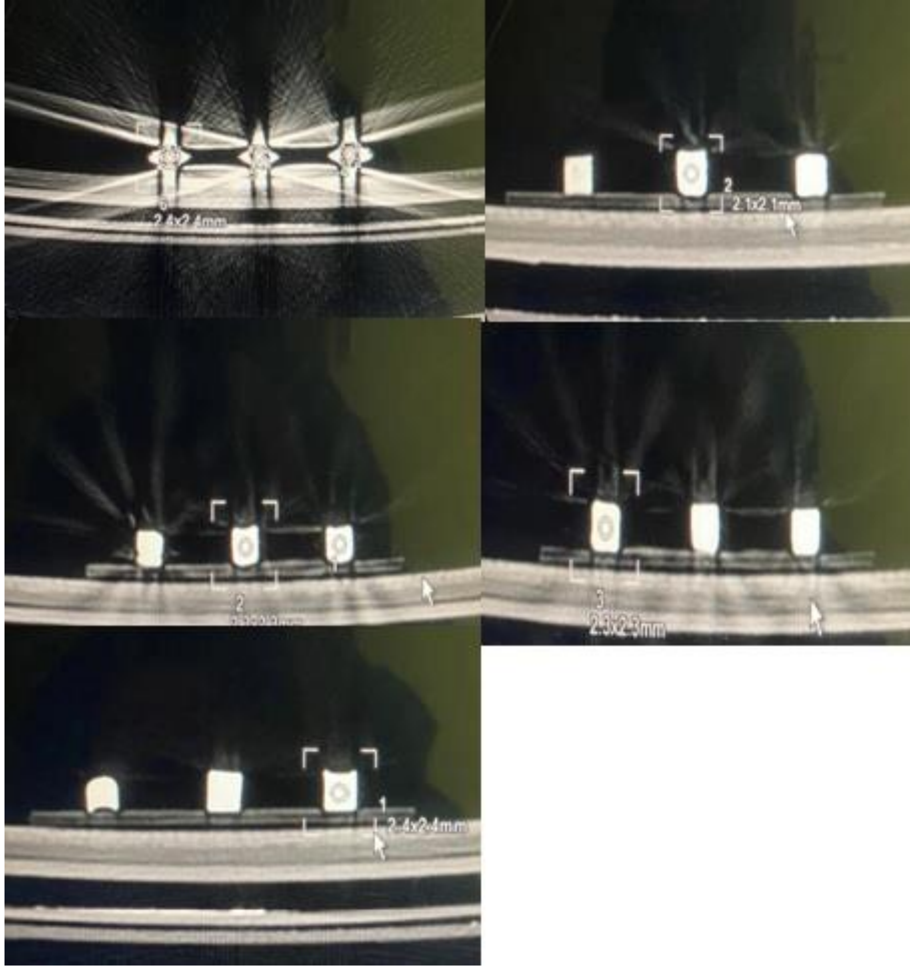

Figure 2: The multi-detector computed tomography (MDCT) image of dental materials scanned by (Alexion, Toshiba, Tokyo, Japan)

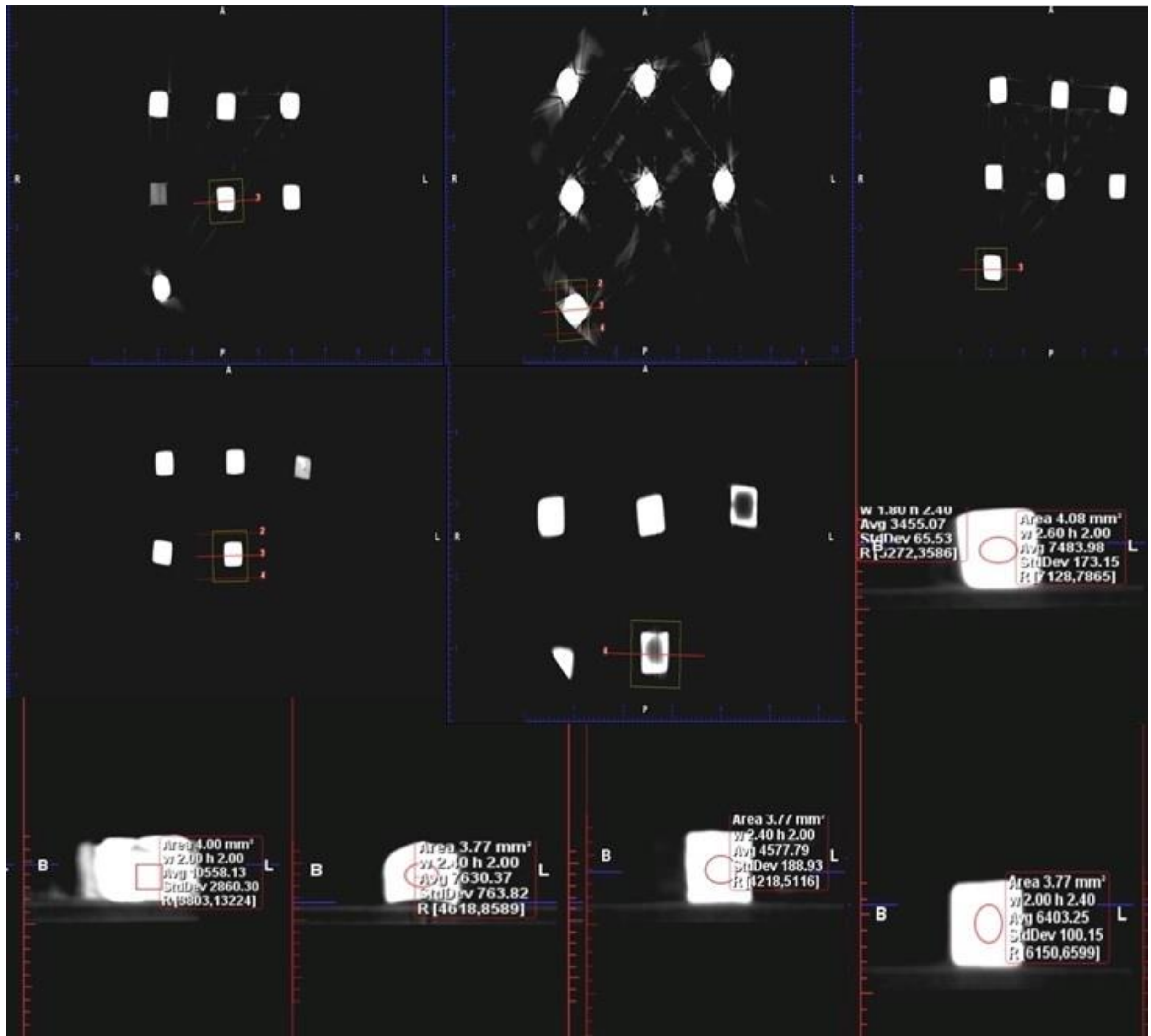

Figure 3: The cone-beam computed tomography (CBCT) image of dental materials scanned by (Planmeca, Helsinki, Finland)