UNIVERSIDADE FEDERAL DE UBERLÂNDIA

FACULDADE DE ODONTOLOGIA

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EVALUATION OF EFFICIENCY OF DIFFERENT IMAGING METHODS AND SOFTWARES TO ANALYSE RADIOPACITY OF CONVENTIONAL BULK FILL COMPOSITE RESINS

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Trabalho de conclusão de curso apresentado a Faculdade de Odontologia da UFU, como requisito parcial para obtenção do título de Graduado em Odontologia.

Orientador: Prof. Dr. Carlos José Soares

Co-orientadora: Me. Luciana Mendes Barcelos

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TRABALHO DE CONCLUSÃO DE CURSO

ATA DA COMISSÃO JULGADORA DA DEFESA DE TRABALHO DE CONCLUSÃO DE CURSO DO (A) DISCENTE **João Vítor Goulart** DA FACULDADE DE ODONTOLOGIA DA UNIVERSIDADE FEDERAL DE UBERLÂNDIA.

No dia **26 de junho de 2019**, reuniu-se a Comissão Julgadora aprovada pelo Colegiado de Graduação da Faculdade de Odontologia da Universidade Federal de Uberlândia, para o julgamento do Trabalho de Conclusão de Curso apresentado pelo(a) aluno(a) **João Vítor Goulart**, COM O TÍTULO: **"EVALUATION OF EFFICIENCY OF DIFFERENT IMAGING METHODS AND SOFTWARES TO ANALYSE RADIOPACITY OF CONVENTIONAL BULK FILL COMPOSITE RESINS".** O julgamento do trabalho foi realizado em sessão pública compreendendo a exposição, seguida de arguição pelos examinadores. Encerrada a arguição, cada examinador, em sessão secreta, exarou o seu parecer. A Comissão Julgadora, após análise do Trabalho, verificou que o mesmo se encontra em condições de ser incorporado ao banco de Trabalhos de Conclusão de Curso desta Faculdade. O competente diploma será expedido após cumprimento dos demais requisitos, conforme as normas da Graduação, legislação e regulamentação da UFU. Nada mais havendo a tratar foram encerrados os trabalhos e lavrada a presente ata, que após lida e achada conforme, foi assinada pela Banca Examinadora.

Uberlândia, 26 de junho de 2019.

Prof. Dr. Carlos José Soares *Universidade Federal de Uberlândia – UFU*	Aprovado Aprovado/Reprovado
Profª. Drª. Camilla Christian Gomes Moura *Universidade Federal de Uberlândia – UFU*	Aprovado Aprovado/Reprovado
Profª. Drª. Priscilla Barbosa Ferreira Soares *Universidade Federal de Uberlândia – UFU*	Aprovado Aprovado/Reprovado
Luciana Mendes Barcelos *Aluno(a) de doutorado – PPGO/UFU*	Aprovado Aprovado/Reprovado

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SUMÁRIO

Evaluation of efficiency of different imaging methods and softwares to analyse radiopacity of conventional and bulk fill composite resins.

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Running title: Different imaging methods to analyse radiopacity of composite resins.

Keywords: Digital X-ray, radiopacity, bulk fill composite resin.

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Development of laboratory devise for standardization of radiopacity analysis - use for testing efficiency imaging methods to analyse radiopacity of resin composites.

ABSTRACT

AIM: This study aimed to present a laboratory device used for obtain standardized X-ray images and used for analysis of resin composites using two radiographic methods and two imaging process data.

METHODS AND MATERIALS: The device with lead protection and glass visor that stabilize the x-ray tube and permitted the stabilization of the samples and different x-Ray films and sensors was created. Specimens with 5.0mm in diameter and 2.0mm in thickness of 2 nanohybrid (Filtek Z350, 3M-ESPE and Vittra APS, FGM) and 4 bulk fill composites (Filtek Bulk fill Posterior, 3M-ESPE, Opus Bulk Fill Regular (FGM), Opus Bulk fill flow (FGM), and Tetric Evoceram Bulk fill (Ivoclar Vivadent) were tested. The x-ray images were obtained positioning one sample for each resin composite and aluminium step wedge over two sensors: direct digital sensor (Acteon) and Phosphor Plate (VistaScan, Dürr Dental). Images were analysed using two software's (Image J and DBSWIN, Dürr Dental) to calculate the radiopacity level comparing resin composites and also with the aluminium step wedge. Data were analysed by three-way ANOVA followed by Tukey test ($\propto$=0.05).

RESULTS: The developed devise was efficient to protect secondary radiation and to standardize the x-ray images. All resin composite showed recommended radiopacity level irrespective of the radiographic method or software analysis.

CONCLUSION: Bulk fill and conventional composite resins exhibit variability in radiopacity, with values considered above the dentin values. Radiographic methods and software tested showed similarity ranking capacity for radiopacity of the composite resins, changing only the calculated values. The device was able to standardize the different radiographic methods used in this in vitro study to assess radiopacity of restorative materials.

INTRODUCTION

Radiopacity is an essential property of dental restorative materials, allowing to assess the integrity of restorations, detection of secondary lesions as well as to evaluate the interface between the restoration and tooth structure.[1] Composite resins need to be satisfactorily radiopaque to permit them to be differentiated from enamel and dentin as it has the advantage of appear clearly in a radiograph image.[2] Composite resins have been going through changes over the years, such as having its particle size reduced and filler load increased, the use of particles with high atomic numbers, such a barium, strontium, and zirconium to produce a more radiopaque material.[7] Otherwise, if the material has low radiopacity it could mislead to an inappropriate analysis and diagnose.[10]

The International Organization for Standardization (ISO) 4049, defines that the radiopacity of a material must be equal or greater than the same thickness of Aluminium wedge step and should not be less than 0,5 mm of any claimed value by the manufacturer.[5] Aluminium is the reference of choice as it is specified to have radiopacity similar to the dentin for the same thickness, and for the enamel it has approximately twice its radiopacity. [4-14]

Digital system for dental radiology was introduced in 1989, and since then digital radiography has gain popularity in dental practice.[11] Digital systems have been widely used for evaluating radiopacity of dental resin composites. It has many advantages as the reduction of x-ray exposure time and no need of darkroom processing step. Additionally, the image manipulation can be improved through basic and advanced techniques available in the available software's, which permits a dynamic analysis of the produced images. The new methods of intraoral radiographic imaging such as direct digital intraoral (CCD/CMOS) and the semi-direct (Photo stimulate phosphor plates – PSP) can be used in association with different software's for analysis of the images. It is important to carry out studies comparing them in relation to their effectiveness and fidelity to the radiopacity values expected for the varied materials applied to restorative dentistry. Therefore, the aim of this study was to evaluate the radiopacity of bulk-fill and conventional composite resins by using digital radiograph versus plate phosphors, and both analysed by DBS Win and Image J software's. The null hypotheses were that bulk fill and conventional composites would have the same values for radiopacity; and that different techniques and associated software's would result in similar measurement performance.

METHODS AND MATERIALS

Specimen preparation

Six different composites resin commercially available were selected: Filtek Z350 3M ESPE (St Paul, MN, USA), Filtek Posterior Bulk fill 3M ESPE (St Paul, MN, USA), Opus Bulk fill regular (FGM, Joinville, Brazil), Opus Bulk fill flow FGM (Joinville, Brazil), Vittra APS (FGM, Joinville, Brazil), and Tetric Evoceram Bulk fill (Ivoclar, Vivadent, Schaan, Liechtenstein) as shown in Table 1.

The specimens with 2 mm thickness and 6 mm of diameter were produced (n=5), using circular pre-fabricated Teflon matrix and photopolymerized by using Bluephase G2 (Ivoclar Vivadent Schaan, Liechtenstein). To minimize the presence of bubbles and possible imperfections, the matrix was placed on a glass slide covered by polyester strip and after insertion of the material a condenser was used to better adaptation of the composite resin, then, a second glass slide was used to press the material in order to force out excess resin and only then it was taken off, and photoactivated according to the manufacturers' instructions.

Radiographic procedures and imaging process

Specimens were radiographed by the two methods proposed in this study: direct digital CMOS (Complementary metal – oxide – semiconductor) sensor FIT T1 (Acteon, Indaiatuba, São Paulo, Brazil) and Phosphor Plate (VistaScan, Dürr Dental, Bietigheim Specimens were radiographed by the two methods proposed in this study: direct digital CMOS (Complementary metal – oxide – semiconductor) sensor FIT T1 (Acteon, Indaiatuba, São Paulo, Brazil) and Phosphor Plate (VistaScan, Dürr Dental, Bietigheim Bissingen, Germany; size 4; 5.7 x 7.6 cm). They were properly positioned directly on both imaging methods with the aluminium step wedge as shown in Figure 1. Then, all the specimen was positioned inside a device developed for the standardization for in vitro studies, and then the radiographic method of choice was put 20 centimetres away from specimen. The Radiographic Timex 70 E Wall (Gnatus, Ribeirão Preto, Brasil) with exposure of 0.10s to 70kV and 7.0 mA with the sensor for the images from the CMOS, which were directly transferred to a computer by the optical fiber cable and the phosphor plate images was transferred by the Vista scan scanner (VistaScan, Dürr Dental, Bietigheim-Bissingen, Germany).

Radiopacity was measured using ImageJ 1.48 software (Developed by Wayne Rasband, National Institutes of Health, USA) and DBSWIN (VistaScan, Dürr Dental, Bietigheim-Bissingen, Germany). Five measuring points were previously defined on each specimen where the mouse cursor was positioned to collect the value of radiopacity (Figure 2).

The mean of the five calculated values was used as radiopacity level for each composite resin sample. All specimens were analysed by both imaging methods and on both software's (Table 2).

Statistical Analysis

Data of difference of radiodensity were analyzed for normal distribution and homoscedasticity using the Shapiro-Wilk test and Levene's test, respectively. In the initial analysis, the goal was to compare the composites used in this study, therefore; data were analyzed by one-way ANOVA. In the second analysis, the effect of the method used for x-ray images and the measurement software used for carrying out was included in the statistical analysis. Thus, data were analyzed using two-way ANOVA (2 x-ray method × 2 software used). For all analysis, the 95% confidence interval for experimental conditions was calculated to allow comparisons among them.

RESULTS

Figure 1E shows representative radiographs for each composite resin. Radiopacity of different composite resins calculated by suing 2 x-ray systems and 2 softwares are shown in Figure 2. One-way ANOVA of the radiopacity data showed significant influence of composite resin type ($P < 0.001$). Two-way ANOVA x-ray method ($P < 0.001$) and software used ($P < 0.001$), however no significance was observed for the interaction between the evaluated factors ($P = 0.156$). The results obtained showed that the radiopacity varied among the restorative materials, when submitted to the same conditions and distance between radiographic image capture method: specimen of material and x-ray machine, and the same time of radiation exposure. The radiopacity values were shown to be similar within the same radiographic image capture method, however the parameters measured modified significantly.

DISCUSSION

The null hypotheses were rejected, composites resins showed different radiopacity values; additionally the measured method and software demonstrated different values, however they maintained the ranking order of the tested composite resin.

Digital methods of radiography have several advantages such as lower doses of radiation, immediate view of images on computer, disposal of chemical waste and the possibility to manipulate the image and easier data transmission.[12] Radiopacity of dental materials has an important role in restorative dentistry as it allows a better identification between tooth structure and dental material.[1-13] It also allows evaluation of the adaptation of restorations like inadequate proximal contours, marginal adaptation and possible gaps between material and tooth structure.[14] The method applied to evaluate the radiodensity involves the use of specimens with the aluminium step wedge positioned together over the radiograph imaging system. It allows the operator to compare which step of the step wedge equals to each specimen's radiopacity (Yasa *et al.,* 2015).[13]

The present study showed that all composite resins had adequate radiopacity for clinical use. All of them presented higher radiopacity than the same thickness of aluminium, which is recommended by the International Organization for Standardization (ISO 4049). All samples were prepared with two millimetres thick and presented higher radiopacity than 4mm on step aluminium wedge. The use of the aluminium step wedge is highly recommended for studies of radiopacity. However, for a better effectiveness the aluminium step wedge must have at least 98% of pureness (Kapila *et al,* 2015). The step wedge used in this study has 99.7% purity with 10 steps.

The presence of bubbles in the material may change its radiopacity, the selection of five measuring points provided a value of radiopacity for each specimen through the aarithmetic mean of these points, which means that a possible presence of bubbles or other defects in specimen does not have great influence in the present study.[8]

The results showed that when evaluated by ImageJ software, the grayscale receives values ranging from 0 to 256, being that the higher the value, the higher the radiopacity of material. On the other hand, when the evaluation of the phosphorus imaging plate radiographs was analyzed by the DBSWIN software, the grayscale evaluation pattern was exceptionally different, with numbers collected from 631 to 1273 where the lower the value, the higher the radiopacity of material. However even with a different pattern, the order of radiopacity of resins was similar. Tetric Evoceram Bulk Fill was always the most radiopaque and Vittra APS was the less radiopaque, irrespective of x-ray system and software used. In the phosphor plate radiographs, the Opus Bulk fill regular and Filtek Z350 composite resins presented similar radiopacity. However, when used the CMOS sensor, they change positions between each other with the Filtek Z350 presenting itself more radiopaque than Opus Pasta in this case. The others resin brands presented the same position in order of most radiopaque to less radiopaque in all tests done.

Radiopacity of materials are related to the chemical composition.[8] The addition of certain elements with high atomic number in the inorganic part of the material such as zirconia, aluminium, barium, silicon, strontium, zinc, and ytterbium can increase the material's ability to absorb x-rays making it more radiopaque.[6] The greater the quantity of these elements in the composition of the material, the greater its radiopacity. [6-8-9]

The fact that Tetric Evo BKF specimen showed the highest radiopacity in all tests can be justified by its filler composition. There are some chemical elements of high atomic number such as Ytterbium (atomic number 70), Ytrium (atomic number 39) and Barium (atomic number 56) which is the most commonly used element to increase radiopacity on composites resin.[2]

The standardization of distance between imaging method, specimens and aluminum step wedge from radiographic developed device was guaranteed by the use of the standardization of the radiographic method device developed in Dental Research Center Biomechanics, Biomaterials and Cell Biology of Federal University of Uberlândia (Cpbio – UFU). The device promote security because no variation on the position during the tests, so that the results would have higher accuracy. Overall, it was demonstrated that bulk fill and conventional composites have sufficient radiopacity to facilitate its detection when measured with different radiographic methods and processed by different software.

CONCLUSION

Bulk fill and conventional composite resins exhibit variability in radiopacity, but with values considered above the dentin values, there is the viable detection. Radiographic methods and software tested showed similarity in the evaluation of radiopacity of the composite resins, changing only the calculated values. The device was able to standardize the different radiographic methods used in this in vitro study to assess radiopacity of restorative materials.

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Table 1**.** Restorative composites resins used in this study.

Material	**Code**	**Shade**	**Composite type**	**Light activation time**	**Basic composition: Organic matrix/Filler**	**Filler % w/vol**
Filtek Z350 (3M-ESPE)	Z350	A2	Conventional	20 seconds	Bis-GMA, UDMA, TEG-DMA/ Silica and zirconia nanofillers, agglomerated zirconia silica nanoclusters.	78.5/59.5
Filtek Posterior Bulk fill Regular (3M-ESPE)	FILTEK BKF R	A2	High Viscosity Bulk fill	20 seconds	AUDMA, UDDMA, UDMA/ Silica, zirconia, and YbF3.	76.5/59.5
Opus Bulk fill Regular (FGM)	OPUS BKF R	A2	High Viscosity Bulk fill	20 seconds	Urethane-dimetacrylic monomers, stabilizers, fotoinitiators and co-iniators/ Inorganic load of silanized silicon dioxide (silica), stabilizers and pigments	79/—
Opus Bulk fill Flow (FGM)	OPUS BKF F	A2	Low Viscosity Bulk fill	20 seconds	Urethane dimetrhacrylate monomers, stabilizers, canforoquinone and coinitiators./ salinized silica dioxide, salinized barium glass, YbF3.	68/—
Vittra APS (FGM)	VITTRA APS	A2	Conventional	40 seconds	Metacrylate monomers mixtures, photoinitiators composition (APS), co-initiators, stabilizer and silane./Particles of zirconia, silica and pigments.	_
Tetric Evoceram Bulk fill (Ivoclar Vivadent)	TETRIC EVC BKF		High Viscosity Bulk fill	20 seconds	UDMA, Bis-GMA/ Barium glass, ytterbium trifluoride, mixed oxide prepolymer	79/ 61

Table 2. Image Systems and softwares used in this study.

Image System	Manufacturer
Complementary metal oxide semiconductor and Optical fiber FIT T1	Acteon (Indaiatuba, SP, Brasil)
Phosphorus plate 4+	Dürr Dental (Bietigheim – Bissingen, Germany)
Software	**Manufacturer**
ImageJ 1.48	Wayne Rasband (National Institute of Health, USA)
DBSWIN 5.15.1	Dürr Dental (Bietigheim – Bissingen, German)

Table 3. Mean and standard deviation values for radiopacity of composites resins analyzed by different softwares' methods Image J and DBS Win).

Composites Resins	CMOS sensor		Phosphorus plate	
	IMAGE J	DBS WIN	IMAGE J	DBS WIN
Filtek Z350	200.3 ± 7.9	195.2 ± 5.7	163.0 ± 4.9	1145.2 ± 63.3
Filtek Post BKF Reg	208.2 ± 9.7	199.0 ± 7.8	171.7 ± 6.0	1035.4 ± 124.1
Opus BKF Reg	197.3 ± 7.8	192.4 ± 7,58	168.6 ± 2.6	1057.2 ± 159,9
Opus BKF Flow	152.1 ± 12.6	151.0 ± 15.1	147.0 ± 15.7	1313.2 ± 94.0
Vittra APS	96.2 ± 5.8	93.6 ± 6.5	112.2 ± 2.4	1819.0 ± 112.2
Tetric EV BKF	234.0 ± 6.0	225 ± 9.0	193.2 ± 6.7	773.4 ± 34.3

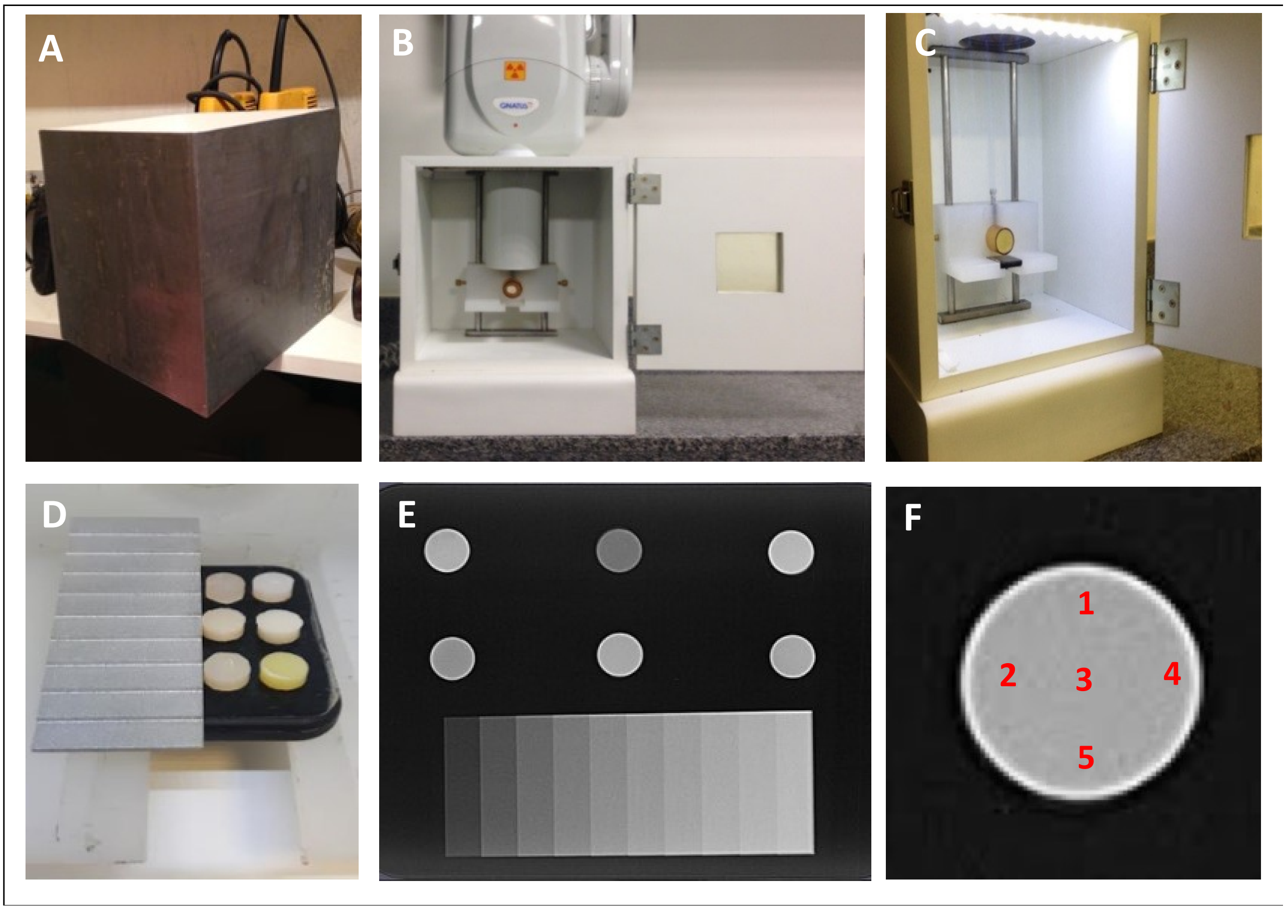

Figure 1. A: Construction of the device developed for the standardization for in vitro studies. B: Device developed for the standardization for in vitro studies stabilizing the x-ray tube. C: Device developed for the standardization for in vitro studies with opened door and lights on. D: Resin specimens and step wedge over the CMOS sensor. E: Radiography of specimens next to step wedge. F: Picture showing the five measuring points to position the mouse cursor.

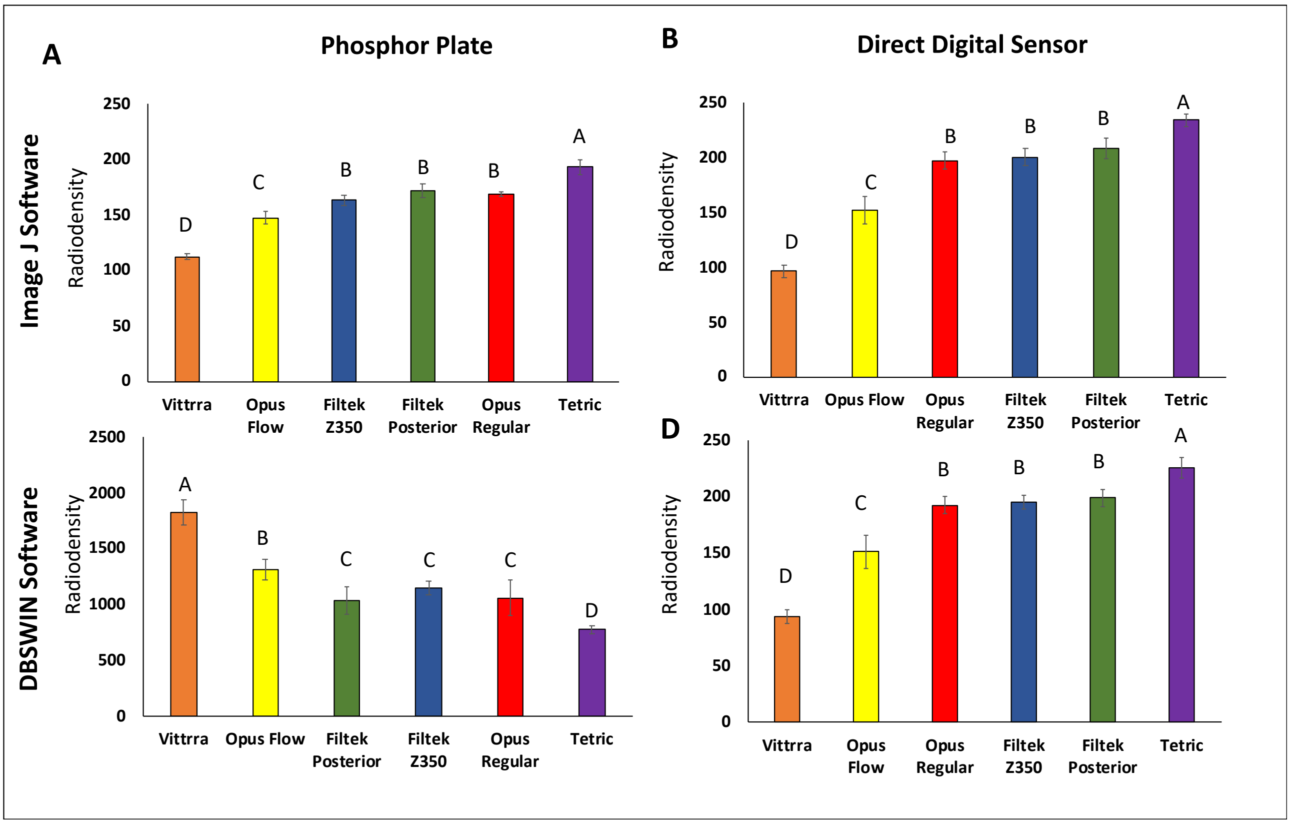

Figure 2. Graphics showing the radiopacity values and statistical analysis of specimens radiographed using the CMOS sensor and phosphor plate analysed by ImageJ and DBSWIN.