https://dx.doi.org/10.22161/ijaers.74.43 **ISSN: 2349-6495(P) | 2456-1908(O)**

Influence of Express® and Vistascan® Image Scanning Systems on the optical density of Endodonic Cements

Gonzalo Martin Souza Rodriguez, Francine Kühl Panzarella, José Luiz Cintra Junqueira, Eduardo Fernandes Marques, Rodrigo Coelho Bezerra de Menezes e Larissa Coelho Bitencourt

Abstract— *This study aimed to assess whether there is influence of the Express and VistaScan scanning systems on the optical density of the image of endodontic cements. 36 specimens were used, 6 of each material, and each material was manipulated and inserted into holes in an acrylic plate supported by a glass plate. The radiographic exposure was performed on phosphorus plates together with an aluminum scale of 9 steps with 1 mm each, this being used as the gold standard. After the periapical radiographic acquisitions, the phosphor sensors were scanned by the Express and VistaScan equipment and saved in TIFF. The optical density of each material was measured in shades of gray and in millimeters of aluminum equivalent (mm Al), according to ISO 6876/2001 standards, using the ImageJ software, twice with an interval of 1 week. The optical density of the filling materials was corrected by subtracting the optical density from the glass plate. To compare the average densities according to the different cement brands, the Tukey test was applied for multiple comparisons. All tests were performed at a 5% significance level. There was a strong correlation between optical densities measured at time 1 and time 2, for optical densities measured from the Express scanning system, Pearson's correlation between measurements made at time 1 and 2 was equal to 0.9983 ($p < 0.0001$) and for measurements made from the VistaScan 0.9998 system ($p < 0.0001$); in both cases the correlations are very close to 1 indicating an almost perfect correlation. In the Express system there was a variation in optical density between 155 and 185, and in the VistaScan system this density varied between 70 and 160. The VistaScan system showed a higher contrast resolution where, through the Analysis of Variance, a greater difference was observed in the densities of the evaluated cements. It was also evident that the measurement via the Express system was numerically superior to VistaScan. There was interaction between the scanning methods and filling cement, mainly in the measurements in the VistaScan system. It was observed that optical density measured in the i-Express system was numerically always higher than the optical density measured in the VistaScan system, and in the Express system, the AH Plus filling cement was the one that obtained the lowest optical density value and the MTA Fillapex reached density larger optics. In the VistaScan system, Sealer 26 cement had the lowest optical density and AH Plus cement had the highest optical density.*

***Keywords*— *endodontic cements; radiopacity; digital images; optical density*.**

I. INTRODUCTION

The perfect hermetic sealing of the root canal system is the main objective of an endodontic treatment, preventing it from acting as a possible source of infection. To achieve such a seal it is necessary, in addition to excellent techniques, the use of good filling materials that satisfy biological and physicochemical requirements. An ideal filling material should be biocompatible with the pulp and periadjacent tissue; waterproof; bacteriostatic or bactericidal, not dye; insoluble in tissue fluids; adherent to dentin and core materials; soluble in common solvent in order to facilitate its removal and also be radiopaque (Costa et al. 2009).

Radiopacity is an essential physical property that allows visualization of endodontic filling material through radiographic examination, particularly in the detection of obscuration of lateral channels; apical deltas; internal restoration and also to monitor the restoration of cements in cases of apical leakage (Costa et al. 2009).

According to Candeiro et al. (2012), the radiopacity of the main and secondary cones and endodontic cement plays an important role in the evaluation of the filling, distinguishing it from the dentin and the alveolar bone, allowing the evaluation of its quality and preservation of the treatment.

Since the use of programs for the analysis of digitized or digital images is able to provide reliable and reproducible results (Tanomaru-Filho et al. 2007; Rasimik et al. 2007), there was a need to compare the optical density different endodontic cements available on the market.

With the emergence of digital image, there was a technological revolution in the acquisition of radiographic images, as well as in the development of computer network systems for image recovery and transmission, eliminating chemical processing, responsible for a large percentage of errors that interfere with image quality, promotes a better visualization of density and contrast depending on the program used and, finally, determines the gray levels from 0 to 255, with intermediate tones where the extremes 0 is black and 255 is white (Attaelmanan, Borg and Grondahl, 2000). In addition, the intraoral sensors used require less radiation than conventional films, reducing the dose absorbed by the patient. One of the disadvantages of digital systems is still the high cost, but the trend over time will be to reduce these costs (White &Pharoah, 2007).

Therefore, it is necessary to know the radiopacity of endodontic cements in digital systems on the market.

II. MATERIALS AND METHODS

2.1 Ethical aspects

This study was submitted and dispensed by the institution's Research Ethics Committee according to the number 2014/0312.

The experimental units were images of 36 specimens made from the insertion of obturator materials in holes 10 mm in diameter and 2 mm deep in an acrylic plate, which were divided into 6 groups according to the brand. shutter material. The measured response variable was the optical density of the filling materials, observed in the images scanned in two indirect digital systems, measured on a gray scale.

As reference values for the optical density of the filling materials, the optical density of the steps of an aluminum scale with 9 steps was obtained, each step being 1 mm thick.

This experimental study followed a completely randomized design, in a 6x2 factorial scheme, and the factors under study were:

• Sealing materials: in 6 experimental levels AH Plus, MTA Fillapex, Endometazone, Sealapex, Pulp Canal Sealer and gutta-percha.

• Image scanning system: Vistascan Mini View and i Express.

Preparation of the Specimens

In the Materials Testing Laboratory, the specimens were made from holes made in an acrylic plate, supported by a 8 mm thick glass plate.

The selected endodontic cements were manipulated following the instructions of each manufacturer for the preparation of the experimental groups and inserted, using the Centrix syringe, in each hole of the acrylic plate under low vibration in order to avoid the formation of bubbles.

A weight of 1 kg was used to overflow and level the surface after handling the cements, removed after setting the materials.

Gutta-percha cones were plasticized with the aid of a lamp at 80ºC for 2-3 minutes. These have in their composition: gutta-percha (19% to 20%) in alpha and beta forms; zinc oxide (60% to 75%) provides rigidity and antibacterial activity to the cones; barium sulfate (1.5% to 17%) are radiopacifiers and resins, waxes and dyes (1% to 4%) (Gurgel-Filho et al. 2003).

Subsequently, the specimens were kept in relative humidity at a temperature of 37 ° C for 48 hours until the final setting of the cements, and kept in the acrylic plate.

Image acquisition and data collection

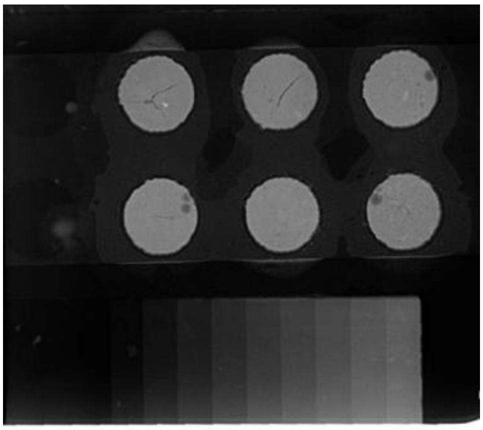

Fig.1: Image of the specimens on the glass plate and the aluminum scale.

Source: Own authorship.

After the laboratory phase; the specimens were sent to the Radiology Clinic of the same institution and radiographic acquisitions using the Heliodent periapical X-ray machine were performed according to the 60 kVp, 10mA and 1.6 seconds regimen.

The specimens supported on the glass plate were radiographed, with the sensors of each system together with the aluminum scale (Figure 1). After the radiographic exposure, the sensors were inserted in the Express and VistaScan Mini View equipment for scanning the images.

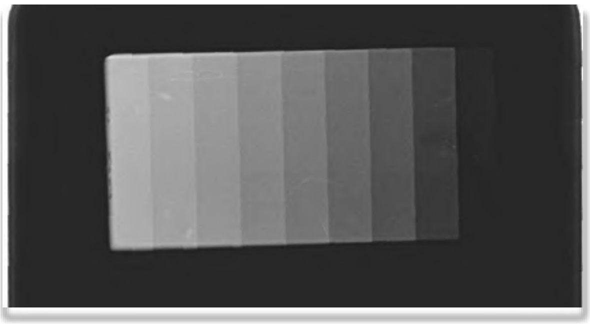

Fig.2: Radiographic image of the aluminum scale without the glass plate.

Source: Own authorship.

Using the same radiographic acquisition regime, the aluminum scale was radiographed and scanned using the sensors of both systems (Figure 2).

The images were saved in files in TIFF format in order to maintain their quality and were examined on a 17 "flat-screen LCD monitor, model 5000: 1 (LG, Seoul, Korea), with a resolution of 1280 x 1024 pixels and maximum color quality (12 bits) in a low light environment.

The values of the optical density, in shades of gray, of the endodontic cements, of the gutta-percha and of the aluminum scale using the ImageJ software (National Institutes of Health NIH, Bethesda, USA) (Figures 3 and 4). repeated twice by the researcher himself, the data being recorded in an Excel spreadsheet (Microsoft, USA).

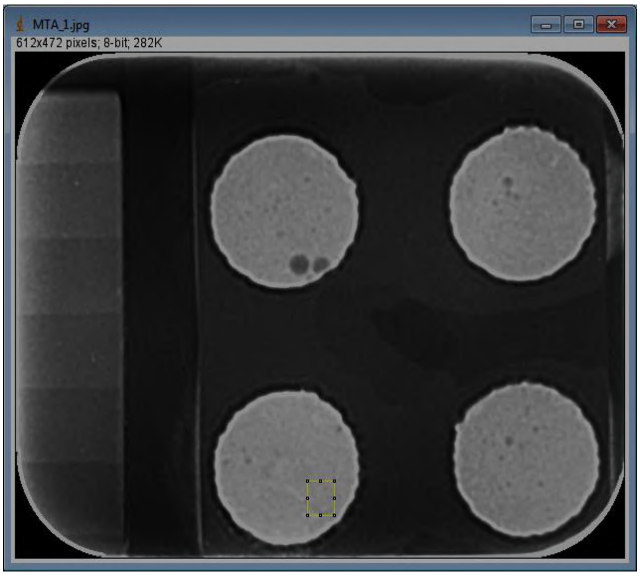

Fig.3: Selection of the region of interest by the ImageJ software.

Source: Own authorship.

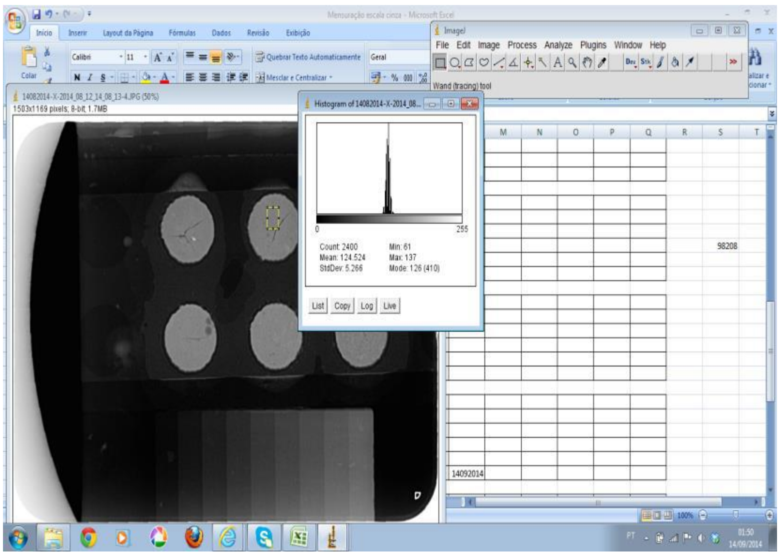

Fig.4: Optical density values obtained using the ImageJ software

Source: Own authorship.

https://dx.doi.org/10.22161/ijaers.74.43 ISSN: 2349-6495(P) | 2456-1908(O)

Statistical analysis

First, the precision of the measurement process or method was evaluated, comparing the measurements made at time 1 with the measurements made at time 2, using Pearson's correlation. To evaluate whether there is a difference in the average optical density between the different image scanning systems and between the different brands of filling materials, the Analysis of Variance method for repeated measures was applied (since the images obtained by different methods are images of the same specimens). To compare the average densities according to the different filling materials, the Tukey test was applied for multiple comparisons. All tests were performed at a 5% significance level. All analyzes were performed using software R version 3.1.1 (www.r-project.org).

III. RESULTS

The aluminum scale showed different shades of gray for the two digital systems, as shown in table 1. The optical density of the filling materials was corrected by subtracting the optical density observed in an image with only the glass plate of the scanning devices (without the bodies of proof), 27,829 for the Express scanning system, and 17,435 for the VistaScan system.

Table 1 - Reference values of the image of the aluminum scale (in shades of gray) scanned in the Express and VistaScan systems, subtracting the optical density of the glass plate.

AL ScaleDegrees	Express (shadesofgray)	VistaScan (shadesofgray)
1	6.832	3.517
2	21.471	13.25
3	40.426	25.999
4	56.710	39.559
5	83.735	50.37
6	110.937	61.751
7	140.507	72.439
8	165.547	83.515
9	179.327	95.976

Source: Own authorship.

5.1 Accuracy of measurements

Firstly, the precision of the measurement process or method was evaluated, comparing the measurements made at time 1 with the measurements made at time 2. For the optical densities measured from the Express scanning system, Pearson's correlation between measurements made over time 1 and 2 was 0.9983 (p value <0.0001) and for measurements made from the VistaScan 0.9998 system (p-value <0.0001); in both cases the correlations are very close to 1 indicating an almost perfect correlation. The absolute difference between the two measurements ranged from 0.020 to 0.817 (mean = 0.334) for the Express system and from 0.001 to 0.799 (mean = 0.353) for the VistaScan system.

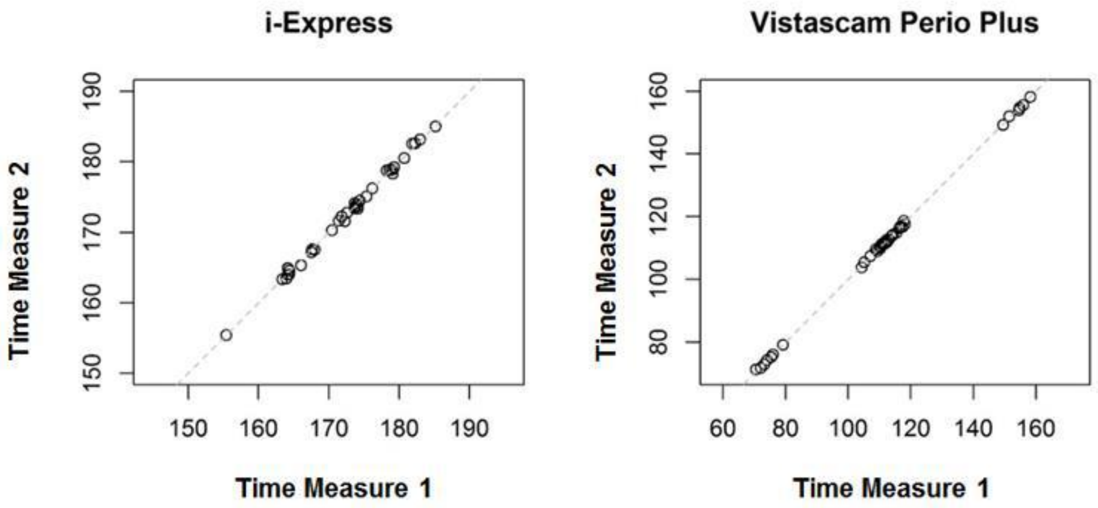

Fig.5: Scatter plot for optical density measured at time 1 and time 2, according to the image scanning system.

Source: Own authorship.

Figure 5 shows the scatter plots between the optical densities measured at time 1 and time 2 according to the scanning systems. It is observed in both graphs that the points are arranged practically on the equality line (dashed line) indicating the strong correlation between the two measurements. Additionally, in the graph of the measurements obtained via Express, we have that the optical density varied between 155 and 185. Note the presence of a possible discrepant point, given by an observation with an optical density around 155, while all other measurements were greater than 163 (this is the optical density of a specimen that received Sealer 26, specimen number 2, As for the measurements obtained via the VistaScan system, the optical density varied between 70 and 160, and the presence of three groups of images is observed in the graph: the first with optical density between 70 and 80, the second with optical density between 110 and 120 and the third with optical density between 150 and 160.

As there was a very strong correlation between the measurements made at time 1 and at time 2, for the subsequent analyzes, the mean density between the two measurements was considered as the optical density.

5.2 Comparison of image scanning systems

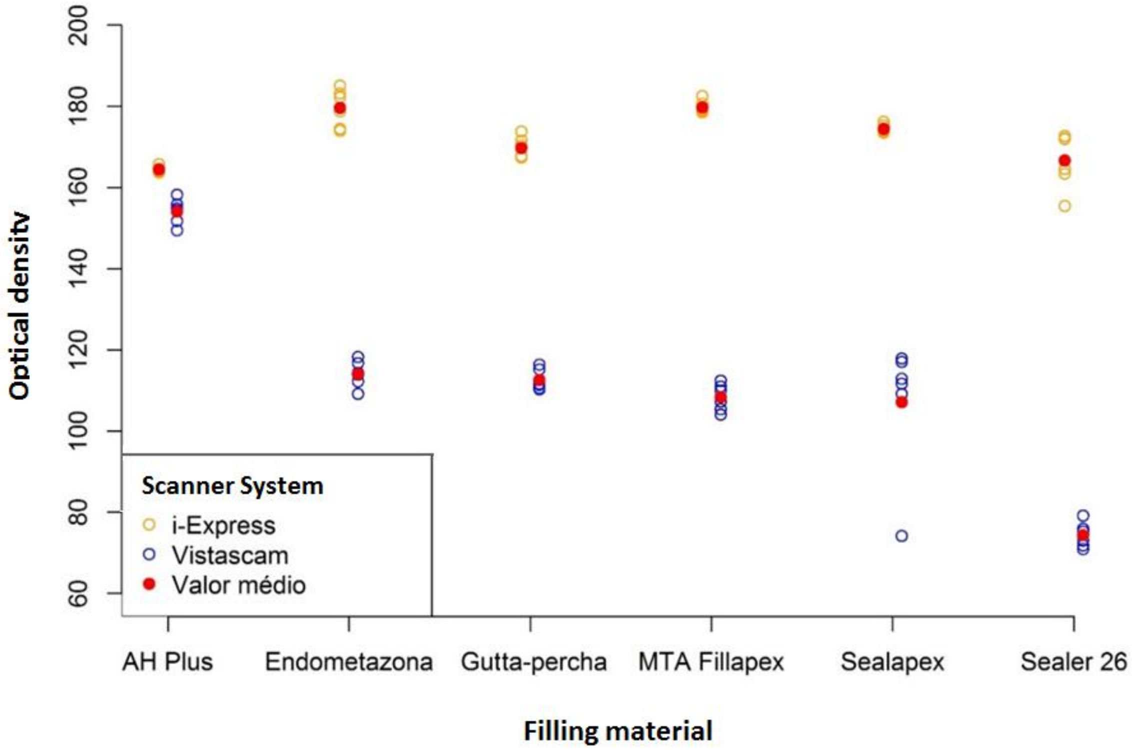

Fig.6: Scatter plot for optical density and filling material.

Source: Own authorship.

Figure 6 shows the graph of dispersion between the measured optical density (and corrected by the optical density of the glass plate) and the filling material used in the specimen. From the graph, the following observations can be made:

The optical density measured via the Express system is, numerically, always higher than the optical density measured via the VistaScan system.

There seems to be an interaction between the scanning system and the filling cement. This is because, the difference in measurements between scanning systems varies with the material used, for example, the difference observed for the images obtained from the specimens that used the AH Plus cement is less than that of the specimens that received the Sealer material 26.

For the Express system there is not much evidence of differences between brands, however there seems to be a difference in optical density between cements for measurements made via VistaScan.

There is a possible discrepant point for the measurements made via VistaScan in the test bodies that received the Sealapex material. The specimen number 3 presented an optical density equal to 74,213, while the other specimens presented an optical density between 109 and 113.

Table 3 shows the mean values and standard deviation for optical density according to the

https://dx.doi.org/10.22161/ijaers.74.43 ISSN: 2349-6495(P) | 2456-1908(O)

brand of the filling material and the image scanning system. A high standard deviation is observed in relation to the other groups, for measurements made via VistaScan with the Sealapex brand. This is due, as noted above, by the presence of an image with an optical density much lower than the density of the other images with the same scanning system and the same brand of filling material. When excluded from the analysis of optical density, the respective mean and standard deviation values change to 113.725 and 3.675, and to the difference 60.851 and 3.628.

In addition, it is noted that the average difference between scanning systems varies from 10 to 92, according to the brands of filling material.

Table 3 - Values of mean and standard deviation (sd) for the optical density according to the mark of the filling material and the scanning system and for the difference.

	Express		VistaScan		Diference	
Filling Material	**average**	**dp**	**average**	**dp**	**average**	**dp**
AH Plus	164,458	0,687	154,062	3,102	10,396	3,363
Endometazone	179,582	4,656	114,090	3,219	65,493	5,599
Gutta-percha	169,742	2,596	112,595	2,555	57,147	3,647
MTA Fillapex	179,744	1,522	108,359	3,328	71,385	4,310
Sealapex	174,434	1,053	107,140	16,463	67,294	16,113
Sealer 26	166,676	6,847	74,381	3,036	92,295	6,048

Source: Own authorship.

To assess whether there is a difference in the average optical density between the different image scanning systems and between the different filling cements, the Analysis of Variance method for repeated measures was applied (since the images obtained by different methods are images of the same bodies evidence). As one of the assumptions of the Analysis of variance is that the variances (or standard deviations) are approximately equal, the image of the specimen that received the Sealapex material was then disregarded from this analysis and obtained via VistaScan, which presented discrepant optical density.

Table 4 shows the result of the Analysis of Variance. There is a statistically significant difference between filling cements and between scanning systems; there is also a statistically significant effect of the interaction between the material's brand and the scanning system.

Table 4 - Result of the Analysis of Variance for repeated measures to test the effect of the filling material mark and scanning system on the optical density of the images.

variationsource	**Degreesoffreedom**	**F**	**P value**
Brand filling material	5	166	< 0,0001
Scanning system	1	5423	<0,0001
Interaction: brand * system	5	190	<0,0001

Source: Own authorship.

Comparison of filling material brands

The next step is to compare the sealer cements according to the images obtained by each of the two scanning systems separately. For that, two models of analysis of variance of one factor were adjusted, one for each system. The analysis of variance showed, in both cases, a p-value <0.0001, indicating that there is a statistically significant difference in the average optical density of the images obtained from different filling materials.

To compare the average densities according to the different brands of filling material, the Tukey test was applied for multiple comparisons. The results are shown in Tables 5 and 6.

Table 5 shows the comparison between the filling cements for the images obtained via Express. There are, in general, two groups of material brands: 1) AH Plus, Gutta-percha and Sealer 26; and 2) Endomentazone, MTA Fillapex and Sealapex. The comparison with the LA scale was made as follows, if the value of a respective step on the scale is contained in the 95% confidence interval presented (95% CI) then there is no significant difference, at the 5% level.

Table 5 - Results of comparisons of the optical density of images obtained via Express.

	Express				
Filling Material	**Average**	**IC 95%**		**Tukey* Test**	**Al Scale degrees ****
AH Plus	164.458	161.551	167.365	a,b	8
Endometazone	179.582	176.676	182.489	b	9
Gutta-percha	169.742	166.836	172.649	a,c	Between 8 and 9
MTA Fillapex	179.744	176.837	182.651	b	9
Sealapex	174.434	171.528	177.341	b,c	between 8 and 9
Sealer 26	166.676	163.770	169.583	a	between 8 and 9

Legend: * Different letters indicate a significant difference at the 5% level. ** Comparison of the 95% CI with the respective step values of the Al scale shown in Table 5.

Source: Own authorship.

Table 6 shows the comparison between the filling materials for the images obtained via VistaScan. In general, three groups of material brands are observed: 1) AH Plus; 2) Endomentazone, Gutta-percha, MTA Fillapex and Sealapex; and 3) Sealer 26.

Table 6 - Results of comparisons of the optical density of the images obtained via VistaScan.

	VistaScan				
Filling Material	**Average**	**IC 95%**		**Tukey* Test**	**Al Scale degrees ****
AH Plus	154.062	151.539	156.585		Higherthan 9
Endometazone	114.090	111.567	116.613	a	Higherthan 9
Gutta-percha	112.595	110.072	115.118	a,b	Higherthan9
MTA Fillapex	108.359	105.836	110.882	b,c	Higherthan9
Sealapex	113.726	110.962	116.490	a,c	Higherthan 9
Sealer 26	74.381	71.858	76.904		7

Legend: * Different letters indicate a significant difference at the 5% level. ** Comparison of the 95% CI with the respective step values of the LA scale presented in Table 5.

Source: Own authorship.

IV. DISCUSSION

New proposed filler cements must have their physico-chemical and biological properties tested. The American National Institute, American Dental Association and the International Organization for Standardization have defined standards and standardized assessment tests, among other parameters, configuration time, flow, film thickness, solubility, radiopacity, dimensional stability and compressive strength of endodontic cements (ANSI / ADA, 2008, ISO 2012).

The radiopacity of aluminum is considered a standard reference because its radiopacity has been described as similar to that of dentin, since 1 mm of aluminum is equivalent to 1 mm of dentin (Akcay et al, 2012). The radiopacity of dental materials has been compared to steps on a scale and identified as millimeters of aluminum equivalent (mm Al).

The results obtained in this research demonstrated that all studied cements had an optical density higher than dentin, which is considered ideal, as recommended by ISSO 6876/2001 and ANSI / ADA, in

https://dx.doi.org/10.22161/ijaers.74.43 ISSN: 2349-6495(P) | 2456-1908(O)

agreement with other works found in the literature (Aznar et al., 2010; Carvalho Filho et al., 2008; Bodrumulu et al., 2007).

Several studies, such as Tanomaru-Filho et al. (2007), Resende (2008) Carvalho Júnior et al. (2007) and Viapiana et al., (2014) evaluated the physical-chemical properties of endodontic cements through different digitization systems where AH Plus showed a higher optical density being used as the gold standard for comparisons with other endodontic cements (Garrido et al. 2010).

The optical density values obtained at time 1 and time 2 showed a very strong correlation between the two measurements, as seen in figure 9. This can be attributed to the Image J measurement system, which is simple and reproducible and has been used in numerous studies such as those by Costa et al. (2002) and Aznar et al. (2010). In the measurements obtained via Express, it was observed that the optical density varied between 155 and 185. As for the measurements obtained via the VistaScan system, the optical density varied between 70 and 160, and the presence of three groups of images: the first with optical density between 70 and 80, the second with optical density between 110 and 120 and the third with optical density between 150 and 160.

In the Express system, the AH Plus filling cement had the lowest optical density and the MTA Fillapex reached the highest optical density. In the VistaScan system, Sealer 26 cement had the lowest optical density and AH Plus cement had the highest optical density.

The optical density measured via the Express system was, numerically, always higher than the optical density measured via the VistaScan system. It should be noted that in the present study, the contrast resolution in the Express system was 14 bits while in the VistaScan system it was 16 bits. The spatial resolution in Express was 14.3 Lp / mm whereas in VistaScan it was 24.1 Lp / mm. These data corroborate those obtained by Molander et al. (2004) where they concluded that a greater bit depth improves the image quality.

The difference in contrast resolution in radiographic images, due to the interaction of the characteristics of the linear attenuation coefficient of the tissues being radiographed White &Pharoah (2007) corroborate the results of Duarte et al. 2009; and Brito-Júnior et al. 2012, which consider the differences in radiopacity between the obturators, due to the different atomic composition and interaction with X-rays. An analysis of the formulation of these materials revealed that they have radiopacifying agents.

AH Plus contains zirconium oxide, which contributes to greater radiopacity compared to the other tested fillers (Tanomaru et al. 2004). These studies explain the differences in densities in the evaluated systems where the interaction of radiopacifiers and the different contrast and spatial resolutions justify the differences in the densities of the evaluated cements.For the Express system there was not much evidence of differences between the brands, however there seems to be a difference in the optical density between the cements for the measurements made via VistaScan.

Table 3 shows the mean values and standard deviation for optical density according to the brand of the filling material and the image scanning system. A high standard deviation was observed in relation to the other groups, for measurements made via VistaScan with the Sealapex brand. This is due, as noted above, by the presence of an image with an optical density much lower than the density of the other images with the same scanning system and the same brand of filling material. If we remove this image with discrepant optical density from the analysis, the respective mean and standard deviation values change to 113.725 and 3.675, and to the difference 60.851 and 3.628. In addition, it was noted that the average difference between scanning systems ranged from 10 to 92, according to the brands of filling material.

According to the results of the Analysis of Variance in table 4, there was a statistically significant difference between the sealer cements and between the scanning systems; there was also a statistically significant effect of the interaction between the material's brand and the scanning system. The analysis of variance showed, in both cases, a p-value <0.0001, indicating that there is a statistically significant difference in the average optical density of the images obtained from different filling materials.

Two groups of material brands were observed in Table 5, in the Express system: 1) AH Plus, Gutta-percha and Sealer 26; and 2) Endomentazone, MTA Fillapex and Sealapex. In the Vista Scan system, table 6, three groups of material brands were observed: 1) AH Plus; 2) Endomentazone, Gutta-percha, MTA Fillapex and Sealapex; and 3) Sealer 26.

Endodontic cements are classified according to their composition, zinc oxide eugenol (Endofil), calcium hydroxide (Sealapex), resinous (Sealer 26 and AH Plus) and Silicone (Roeko Seal), as verified in the studies by Tanomaru et al. (2004) and Aznar et al. (2010), where

https://dx.doi.org/10.22161/ijaers.74.43 *ISSN: 2349-6495(P) | 2456-1908(O)*

resinous trees presented greater radiopacity, with AH Plus being the only one to present greater radiopacity than gutta percha.

Due to its great radiopacity, easy handling and flow, AH Plus resin cement has been used as the gold standard for comparisons with other endodontic cements (Garrido et al. 2010).

Studies that evaluate the radiopacity of filling cements should be carried out periodically, since manufacturers have been constantly reformulating the composition of their products in order to achieve better properties. In view of the results presented, further research is suggested in relation to the method of evaluating the optical density of obturator materials in endodontics using new technologies for image acquisition as well as a standardization in digital systems in relation to pixel size, contrast resolution and resolution space.

V. CONCLUSION

From the results presented, differences were observed in the optical density of the cements and the influence of scanning systems on the optical density of the studied cements.

REFERENCES

[1] Akcay I, Ilhan B, Dundar N. Comparison of conventional and digital radiography systems with regard to radiopacity of root canal filling materials. IntEndod J. 2012.

[2] Almeida PM, Antonio MPS, Moura AAM. Estudo comparativo da radiopacidade de quatro cimentos obturadores de canais radiculares. RevInstCienc Saúde. 1998; 16(1): 27-30.

[3] Assmann E, Scarparo RK, B€ottcher DE, Grecca FS. Dentin bond strength of two mineral trioxide aggregate based and one epoxy resin-based sealers. J Endod. 2012;38:219-21.

[4] Aznar FDC, Bueno CES, Nishiyama CK, Martin AS. Radiopacidade de sete cimentos endodonticos avaliada através de radiografia digital. RGO RevistaGaucha de Odontologia. 2010; 58(2): 181-184.

[5] Baksi BG, Eyüboğ TF, Şen BH, Erdilek N. The effect of three different sealers on the radiopacity of root fillings in simulated canal. Oral Surg Oral Med Oral Pathol Oral RadiolEndod. 2007; 103:138-41.

[6] Beer R, Gängler P, Rupprecht B. Investigation of the canal space occupied by gutta-percha following lateral condensation and thermomechanical condensation. Int Endod J. 1987; 20(6):271-5.

[7] Beyer-Olsen EM, Orstavik D. Radiopacity of root canal sealers. Oral Surg. 1981; 51(3): 320-8.

[8] Bodamezi A, Bortoluzzi EA, Munhos EA, Bernardineli N, Moraes IG, Bradamante CM. Radiopacidade do cimento portland adicionado de agentes radiopacificadores em diferentes proporçoes. Rev Inst CiencSaude. 2009; 27(2):167-70.

[9] Bodrumulu E, Sumer AP, Gungor K. Radiopacity of a new root canal sealer, epiphany. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 2007;104(5):58-61.

[10] Brito-Júnior M, Santos LAN, Faria-e-Silva AL, Pereira RD, Sousa-Neto MD. Ex vivo evaluation of artifacts mimicking fracture lines on cone-beam computed tomography produced by different root canal sealers. Int Endod J.2012;47:26-31.

[11] Camillerí J, CutajarA,Mallía B. Hydration characteristics of zirconium oxide replaced Portland cement for use as a root-end filling material.Dental Materials 2011;27;845-54.

[12] Candeiro GT, Correia FC, Duarte MA, Ribeiro-Siqueira DC, Gavini G. Evaluation of Radiopacity, pH, Release of Calcium Ions, and Flow of a Bioceramic Root Canal Sealer. J Endod. 2012;38(6):842-5.

[13] Carvalho-Junior JR, Correr-Sobrinho L, Correr AB, Sinhoreti MA, Consani S, Sousa-Neto MD Radiopacityof root fillingmaterialsusing digital radiography. Int Endod J 2007; 40, 514–20

[14] Cederberg RA, Frederiksen NL, Benson BW, Shulman JD. Influence of the digital image display monitor on observer performance. DentomaxillofacRadiol1999;28:203-7.

[15] Chotas HG, Floyd CE, Dobbins JT, Ravin CE. Digital chest noise ratio as a function of kilo voltage with matched exposure risk. Radiology 1993;186:395-8.

[16] Cohen S, Blanco L, Berman L. Vertical root fractures: clinical and radiographic diagnosis. J Am Dent Assoc.2003;134:434-41.

[17] Coomaraswamy KS,LumleyPJ,Hofmann MP. Effect of bismuth oxide radioopacifiercontento n the material properties of an endodontic Portland cement-based(MTA-like)system.Journal of Endodontics 2007;33:295-8.

[18] Constante IGT, Bardauil MRRS, Carvalho CF, Davidowicz H, Moura AAM. Avaliação da radiopacidade de cimentos endodonticos pelo sistema RVG- Radiovisiografia. RevInstCiencSaude. 2007; 25(1):39-45.

[19] Costa FF, Gaia BF, Umetsubo OS, Cavalcanti MG. Detection of horizontal root fracture with small-volume cone-beam computed tomography in the presence and absence of intracanal metallic post. J Endod. 2011;37:1456-9.

[20] Costa CCA, Netto CM, Koubik ACGA, Michelotto ALC. Aplicações clínicas da tomografia computadorizada cone beam na endodontia. RevInstCienc Saúde. 2009; 27(3):279-86.

[21] Costa RF, Scelza MFZ, Costa AJO. Radiopacidade de cimentos endodonticos: avaliação pela intensidade pixel. J Bras Clin Odontol Int, Curitiba. 2002; 6(32):137-139.

[22] CutajarA,MallíaB,AbelaS,Camilleri J (2011)Replacement of radiopacifier in mineral trioxide aggregate ;characterization and determination of physical properties.Dental materials 27,879-91.

[23] DenryH,Holloway JA, Nakkula RJ, Walters JD, (2005) Effect of niobium content on the microstructure and

thermal properties of fluorapatite glass-ceramics. Journal of Biomedical Materials Research.Part B, Applied Biomaterials 75,18-24.

[24] Duarte MAH, Kadre GDOL, Vivan RR, Tanomaru JMG, Tanomaru Filho M, Moraes IG. Radiopacity of Portland cement associated with different radiopacifying agents. J Endod. 2009;35:737-40.

[25] Durack C, Patel S. Cone beam computed tomography in endodontics. Braz Dent J. 2012;23:179-91.

[26] Eickholz HJ, Kolb I, Lenhard M, Hassfeld S, Staehle HJ. Digital radiography of interproximal caries: effect of different filters.Caries Res 1999;33:234-41.

[27] Ferreira FBA, Souza PARS, Vale MS, Tavano O. Radiopacidade de cimentos endodonticos avaliada pelo sistema de radiografia digital. Rev Faculdade de Odontologia de Bauru. 1999; 7(1/2): 55-60.

[28] Garrido AD,LiaRC,FrancaSC,da Silva JF,Astolfi-Filho S,Sousa-Neto MD (2010) Laboratoryevaluationofthephysicochemicalpropertiesof a new root canal sealerbasedonCopaiferamultijugaoil-resin.InternationalEndodonticJournal 43,283-91.

[29] Guerreiro-TanomaruJM,Duarte MA ,Gonçalves M, Tanomaru- Filho M(2009).Radiopacityevaluationof root canal sealerscontainingcalciumhyddoxideand MTA .Braziliam Oral Research 23,119-23.

[30] Gomes Cornélio AL, Salles LP,Campos da Paz M, Cirelli JA, Guerreiro-Tanomaru JM, Tanomaru Filho M. Cytotoxicity of Portland cement with different radiopacifying agents: a cell death study. Journal of Endodontics 2011;37:203-10.

[31] Gorduysus M, Avcu N. Evaluation of the radiopacity of different root canal sealers. Oral Surg Oral Med Oral Pathol Oral RadiolEndod. 2009 Sep;108(3):e135-40. Epub 2009 Jul 3.

[32] Hayakawa Y, Farman AG, Kelly MS, Kuroyanagi K. Intraoral radiographic storage phosphor image mean pixel values and signal-to-noise ratio: effects of calibration. Oral Surg Oral Med Oral Pathol Oral RadiolEndod1998;86:601-5.

[33] International Standards Organization. ISO 6876

[34] Dentistry root canal sealing materials;2012

[35] Jakobson SJ, Westphalen VP, Silva Neto UX, Fariniuk LF, Schroeder AG, Carneiro E. The influence of metallic posts in the detection of vertical root fractures using different imaging examinations.DentomaxillofacRadiol. 2013;43:20130287.

[36] KarlinseyRL,Yi K, Duhn CW(2006) Nucleation and growth of apatite by a self-assembled polycrystalline bioceramic..Bioinspiration and Biomimetics 1,12-9.

[37] Khedmat S, Rouhi N, Drage N, ShokouhinejadN,Nekoofar MH. Evaluation of three imaging techniques for the detection of vertical root fractures in the absence and presence of gutta-percha root fillings. IEJ, 45, 1004–1009, 2012

[38] KondylidouSidira et al ,The Society of The Nippon Dental University. Odontology (2013) 101:89–95

[39] Kopper PM, Figueiredo JA, Della Bona A, Vanni JR, Bier CA, Bopp S. Comparative in vivo 25. analysis of the sealing ability of three endodontic sealers in post-prepared root canals. Int Endod J 2003;36:857-63.

[40] Kositbowornchai S, Nuansakul R, Sikram S, SinahawattanaS,Saengmontri S. Root fracture detection: a comparison of directdigital radiography with conventional radiography. DentomaxillofacRadiol. 2001;30:106–9.

[41] LeituneVC ,TakimiA,Collares FM et al.(2013). Niobium pentoxide as a new filler for methacrylate-based root canal sealers. International Endodontic Journal 46,205-10.

[42] Li G. Comparative investigation of subjective image quality of digital intraoral radiographs processed with 3 image-processing algorithms. Oral Surg Oral Med Oral Pathol Oral RadiolEndod2004;97:762-7.

[43] Lisboa FM, Kopper PMP, Figueiredo JAP, Tartarotti E. Estudo da radiopacidade de três cimentos endodonticos por meio da imagem digitalizada. JBE Jornal Bras Endo 2003;4(14):193-197.

[44] Molander B, Gro¨ndhal H-G, Ekestubbe A. Qualityoffilmbasedand digital panoramicradiography. DentomaxillofacRadiol2004;33:32-6.

[45] Nair MK, Nair UP, Grondahl H-G, Webber RL. Accuracy of tuned aperture computed tomography in the diagnosis of radicular fractures in non-restored maxillary anterior teeth. Dentomaxillofac Radiol. 2002;31:299–304.

[46] Ozer SY (2010) Detection of vertical root fractures of different thicknesses in endodontically enlarged teeth by cone beam computed tomography versus digital radiography. J Endod 36, 1245–9.

[47] Rasimick BJ, Shab RP, Musikant BL, Deutsch AS. Radiopacity of endodonic materials on film and digital sensor. J Endod. 2007; 33:1098-1101.

[48] Reeves TE, Mah P, McDavid WD. Deriving Hounsfield units using grey levels in cone beam CT: a clinical application.DentomaxillofacRadiol.2012;41:500-8.

[49] Shrout MK, Russel CM, Potter BJ, Powell J, Hildebolt CF. Digital enhancement of radiographs: can it improve diagnosis?J Am Dent Assoc 1996;127:469-73.

[50] Sydney GB, Ferreira M, Leonardi DP, Deonizio MDA, Batista A. Análise da radiopacidade de cimentos endodonticos por meio de radiografia digital. Rev OdontoCienc. 2008; 23(4):338-341.

[51] Tagger M, Katz A. A standard for radiopacity of root-end (retro-16. grade) filling materials is urgently needed. Int Endod J 2004;37:260-4.

[52] Tanomaru Filho M, Gouveia JE, Tanomaru JMG, Gonçalves M. Evaluation of the radiopacity of calcium hidroxide and glass-10 nemer- based root canal sealers. Int Endod J. 2008; 41(1):50-53.

[53] Tanomaru Filho M, Gouveia JE, Tanomaru JMG, Gonçalves M. Radiopacity evaluation of new root canal filling materials by digitalization of images. J Endod. 2007; 33(3):249-251.

[54] Tanomaru JMG, Cezare L, Gonçalves M, Tanomaru Filho M. Avaliação da radiopacidade de cimentos endodônticos

por meio da digitalização de imagens radiográficas. J Appl Oral Sci. 2004; 12(4):355-7.

[55] Tanomaru JMG, Duarte MA, Gonçalves M, Tanomaru-Filho M. Radiopacity evaluation of root canal sealers containing calcium hydroxide and MTA. Braz Oral Res. 2009 Apr-Jun;23(2):119-23.

[56] Tanomaru-Filho M, Bosso R, Viapiana R, Guerreiro-Tanomaru JM. Radiopacity and flow of different endodontic sealers. Acta OdontolLatinoam. 2013;26(2):121-5.

[57] Taşdemir T, Yesilyurt C, Yildirim T, Er K. Evaluation of the radiopacity of new root canal 13. paste/sealers by digital radiography. J Endod2008;34:1388-90.

[58] ViapianaR,GuerreiroTanomaruJMG,DuarteMAH,Tanomaru-Filho M,Camilleri J Dental Materials 30(2014)1005-1020

[59] Wenzel et al(Oral Surg Oral Med Oral Pathol Oral RadiolEndod 2007;103:418-22)

[60] Wenzel A, Kirkevang LL. High resolution charge-coupled device sensor vs. medium resolution photostimulable phosphor plate digital receptors for detection of root fractures in vitro. Dent Traumatol2005;21:32–6.

[61] Wenzel A, Haiter-Neto F, Frydenberg M, KirkevangLL.Oral Surg Oral Med Oral Pathol Oral RadiolEndod 2009;108:939–45.

[62] Shintaku HW, Jaqueline S. Venturin, Marcel Noujeim, Stephen B. Dove Dental Traumatology 2013; 29: 445–449; doi: 10.1111/edt.12041.

[63] White SC, Pharoah MJ. Radiologia oral fundamentos e interpretação. 5° ed. Rio de Janeiro: Elsevier;2007.cap.12:imagem digital, p.225-245.