Differences of Micro-CT evaluation of the obturation sealing capability between thermoplastic carrier-based condensing techniques and lateral heat condensation techniques

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ABSTRACT

Introduction: Root canal filling is an important part of root canal treatment that aimed to seal the root canal system, to prevent bacterial penetration and their toxins into periradicular tissues and to provide favourable environment for periapical healing. Thermoplasticized technique were developed to produce filling with homogenous mass, to achieve optimal sealing ability and to increase the quality of root canal filling. The aim of this study is to analyzed differences of Micro-Computed Tomography (Micro-CT) evaluation of the obturation sealing capability between thermoplastic carrier-based condensing techniques and lateral heat condensation techniques. **Methods:** This study was conducted under an in-vitro quasi experimental methode to 36 specimens of maxillaris centralis incisivus which were divided to 3 groups, (A) thermoplasticized carrier-based technique (GuttaCore System), (B) warm lateral condensation technique (heat carrier SystemB), (C) cold lateral condensation as control group. Sealing ability is evaluated based on the measurement results of volume percentages of filling material and sealer, volume of void, and surface density, that which was calculated from the 3D volumetric image of Micro-CT device. Data were statistically analysed using Analisis of Variance (ANOVA) and t-test. **Result:** The result showed significant difference of percentage filling material and sealer volume in apical third ($p<0.05$), whereas there were no significant differences of void volume in apical third, middle third, coronal third or along the canal ($p>0.05$). **Conclusion:** Thermoplastized carrier-based technique is not better than warm lateral technique.

Keywords: sealing ability; root canal filling; thermoplasticized carrier-based technique; warm lateral technique.

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INTRODUCTION

Root canal obturation is an important stage in endodontic treatment aimed to close the root canal system from apical, lateral and coronal.[1] The successful of endodontic treatment depends on biomechanical preparation, obturation and apical closure through coronal root canal system in three dimentionally.[1,2,3,4] According to radiographic analysis study of Alrwitai et al[5], showed that 48% endodontic treatment failure associated with inadequate obturation. Hermetic obturation with good sealing ability capacity are obtained from combination of gutta percha and sealer material and provide a tight and solid barrier to prevent bacterial and toxins reinfection between the space of root canal system and periradicular tissue.[6,7,8,9]

Cold lateral condensation technique is a gold standard obturation technique commonly used because it has good apical control, easy to perform and in expensive.[9,10,11] This technique produces less homogenous obturation since there was a gap between the master and accessories cones of gutta percha due to the using of spreader while condensation and it requires more sealers to minimize voids between gutta percha filling and sealer, and along the obturation material with root canal walls.[8,12,13] Gaps or voids that exist between the root canal obturation and the walls should be a pathway of microleakage which decrease the quality of obturation and affect the outcome of endodontic treatment.[14,15]

The thermoplasticized condensation technique was developed to increase the density and flow ability of the obturation material covering the irregularity of the root canal.[15,16,17] The warm lateral condensation technique was performed by applying a heat-carrier to soften gutta percha in the root canal and condensing laterally.[9,10,11] This technique is a modification of cold lateral condensation and warm vertical condensation technique.[16] The recent carrier-based system, GuttaCore (Dentsply, mailefer, Switzerland) carrier-based system which is heated using Thermaprep® 2 (Dentsply, mailefer, Switzerland) which can be performed more easily and become an alternative to the warm vertical condensation technique.[7,18] Various studies were conducted to assess the quality of obturation of root canal with varying obturation techniques. Based on researcher observation, there is various studies were conducted to assess the quality of root canal obturation with different experimental approaches such as electrochemical methods, fluid filtration, radiography, SEM analysis, and computed tomography. Micro-CT is a 3D imaging technique utilizing X-rays to see inside an object, slice by slice. Scan subject of Micro-CT imaging show a small scale with greatly increased resolution. Based on above definition of Micro-CT, researcher can do deep analyze of root canal obturation. The aim of this study is to analyzed differences of Micro-Computed Tomography (Micro-CT) evaluation of the obturation sealing capability between thermoplastic carrier-based condensing techniques and lateral heat condensation techniques.

METHODS

Sample selection and preparation

This research was conducted with an in vitro experimental method at the Conservative Dentistry Clinic, Faculty of Dentistry, Universitas Padjadjaran, using 36 intact maxillary central incisors, without caries, straight roots with closed apices and a maximum length of 25 mm. The teeth are soaked in saline solution for 24 hours, then the cavity access was opened. Working length was measured using a K-file # 10 followed by root canal preparation using a rotary system ProTaper NEXT (Dentsply, Mailefer, Switzerland) and endomotor X-smartPLUS (Dentsply, Mailefer, Switzerland) until the file X2 and irrigation using a solution of NaOCl 5.25 % and EDTA 17%.

The root canals were dried using paper point and then divided into 3 groups for each obturation technique; Group A: carrier-based thermoplastic condensation technique, Group B: warm lateral condensation technique, Group C: cold lateral condensation technique (control).

Group A: Root canals were verified using verifier X2 then a premixed calcium silicate sealer was applied through a syringe to the root canals. GuttaCore X2 was heated in an oven, then inserted into the root canal with mild pressure and was vertically condensed with a plugger. **Group B:** Premixed calcium silicate sealer was applied

through a syringe to the root canal. The main Gutta-percha X2 (Dentsply, Mailefer, Switzerland) was inserted in the root canal, followed by gutta-percha accessories then condensed laterally using a spreader until the root canal was full. The heat carrier tip device (System B, SybronEndo, USA) was inserted into the root canal as deep as 4 mm from apically for 3 seconds. The same procedure was carried out until the root canal was full. **Group C:** Premixed calcium silicate sealer was applied through a syringe to the root canal. The main Gutta-percha X2 (Dentsply, Mailefer, Switzerland) was inserted in the root canal, followed by gutta-percha accessories then condensed laterally using a spreader until the root canal was full. The excess gutta percha were cut with a hot excavator and condensed with a plugger. The coronal part of each sample group was covered by Smart Dentin Replacement (Dentsply, Mailefer, Switzerland) and soaked in artificial saliva to be stored in a 37 ◦C incubator for 24 hours then rinsed, dried, and buried in plasticine.

Micro-CT analysis

Micro-CT scanning

Specimen analysis was performed at the Micro-CT Laboratory, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung. Specimens that had been buried in plasticine were scanned using a Bruker SkyScan 1173 High Energy Micro-CT X-Ray Micro-Computed Tomography Scan (Figure 1). Scanning was performed with 360° rotation mode, rotation step 0. 20°, X-ray source uses 100 kV energy, 80 µA current, 1.0 mm Al filter, with 500 ms exposure time and produces a projected image with a spatial resolution of 11.40 µm/pixel.

Micro-CT image reconstruction

Scanning image reconstruction was performed using NRecon software with the GPUReconServer kernel based on the Feldkamp backpropagation principle, resulting in a gray-scale 8-bit bitmap image. Stacks of images contain complete information on structures in 3D space, which are visualized in the form of orthoslice or visual volumetric 3D. The visual images of each structure were coded differently, dentinal root (2D- light purple, 3D-gray), gutta percha (green), carrier (blue), sealer (yellow), and voids (2D- dark purple, 3D-red) used in qualitative analysis. The results of sample testing were analyzed using CTAnalyser (CTAn) and volumetric images were displayed with the help of the CTVoxel (CTVox) device.

Sealing ability evaluation

Assessment of sealing ability using Micro-CT analysis, determined by parameters including; (1) Fraction of volume ; includes root canal volume (VOI), is determined from the tip apex 0 mm to 12 mm in the direction of coronal root canal, volume of obturation materials; the volume of gutta percha (% Vfm), and the volume of sealer (% Vs), and volume of voids assessed from total porosity (ϕ); includes isolated voids (closed porosity) (Figure 1.a), and voids associated with root canal walls (open porosity) (Figure 1.b). The apical volume (VA) is measured in each apical third region in apical third region (VOI: 0-4 mm), middle volume (VM) is measured from middle third region (VOI: 5-8 mm), and coronal volume (VC) is measured in coronal third (VOI: 9-12 mm), and the entire root canal (VE) is measured from apical to coronal (VOI: 0-12 mm); (2) surface density (S_D), which tendency of root canal obturation to create voids with complex structure and voids distribution based on the ratio between the surface area of voids to VOI.

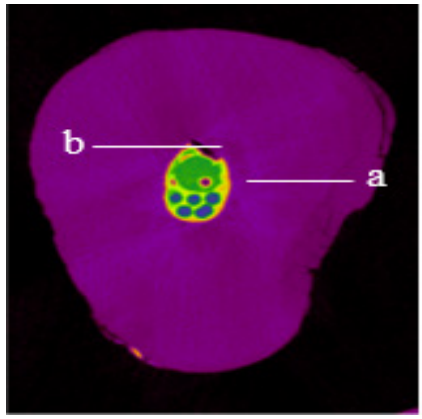

Figure 1. Void Type. a. closed porosity, b. open porosity. (dark purple: dentinal root wall, yellow; sealer; green: master cone gutta percha, blue; accessories cone gutta percha, round purple/black: void)

Statistical analysis

Data were analyzed statistically using Analisis of Varian (ANOVA) with $p < 0.05$ and t-test with $p < 0.05$ significantly different and $p < 0.01$ significantly different.

RESULTS

The result of Micro-CT scanning and reconstruction showed visualization of dentinal root, obturation material including gutta percha, carrier, sealer, and void in 2D and 3D images of each group. Qualitative analysis based on 2D images is displayed in graphics (Figure 2) and the slices of each 2.0 mm from apical to 12.0 mm in the coronal direction (Figure 3). Graphics and 2D slices images show that the carrier-based thermoplastic condensation technique has the smallest percentage of voids in each apical

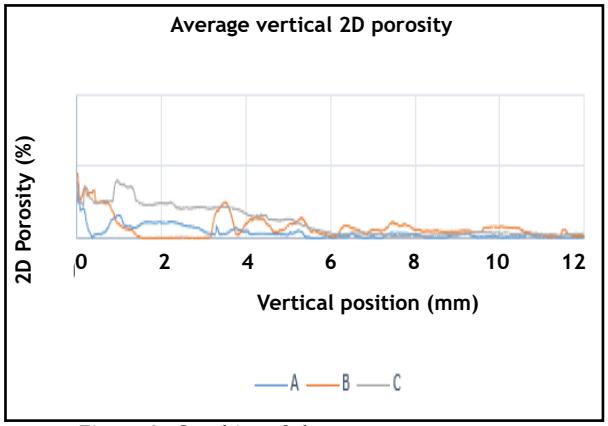

Figure 2. Graphics of the average percentage of total 2D porosity.

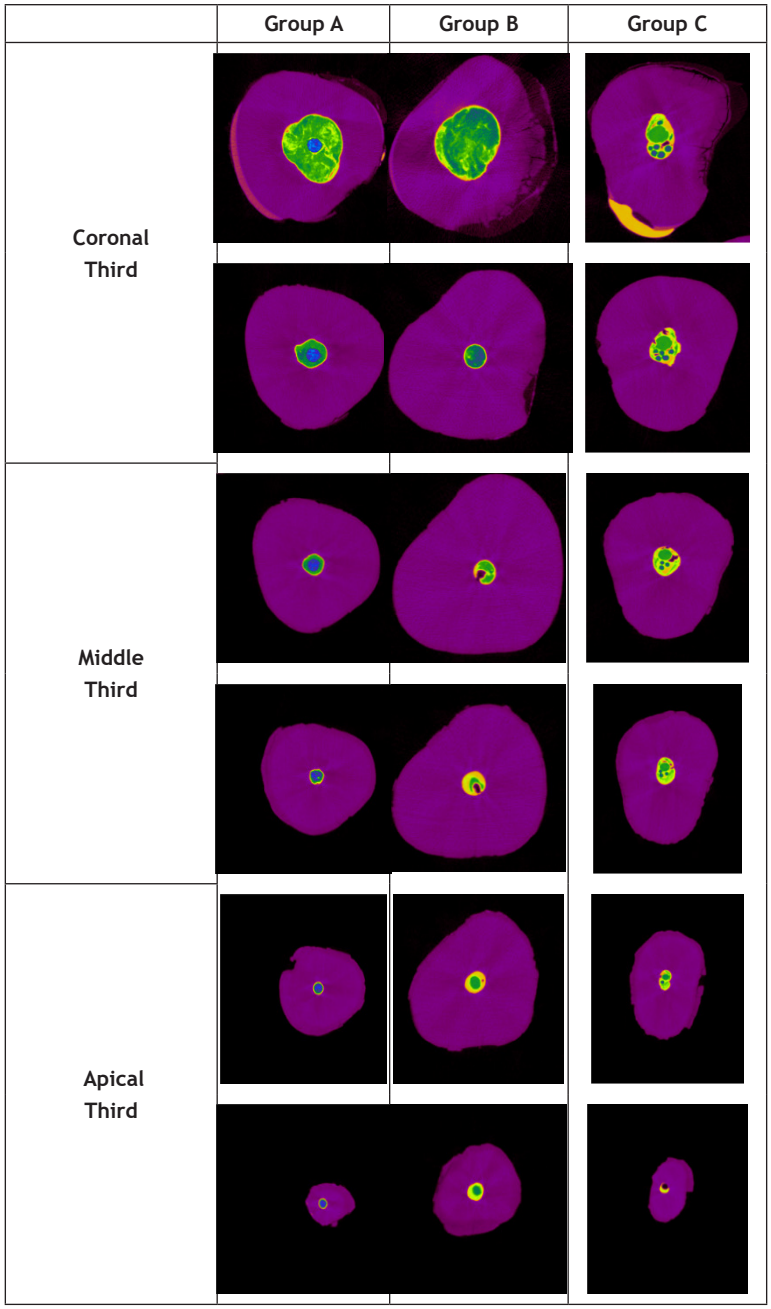

Figure 3. Overview of 2D slices from apical to coronal (Source: 3D Micro-CT volumetric visual image)

third, middle third and coronal third of the root canal. The warm lateral condensation technique shows a greater percentage of void in the middle third of the root canal than the apical and coronal sections, while the cold lateral condensation technique has a large percentage of voids in each apical third, middle third and coronal third. The apical third shows a high percentage of void in the three techniques were examined. The results of ANOVA statistical test for measuring the average volume fraction of obturation material are shown in Table 1, and the results of the average of volume and void distribution are shown in Table 2, and the results of the t-test are displayed in Table 3. The results of measuring the average volume of material fillers and sealers showed

Table 1. Fraction of obturation material volume (% Vfm and% Vs).

Group Parameter	n	Mean	SD	SD				P	Interpretation
				VA	VT	VK	VS		
VOI (mm^3)	36	6.09	4.93					-	-
A				1.36	2.99	10.61	14.96		
B				1.12	1.94	6.19	9.16		
C				1.83	3.98	6.55	12.36		
% Vfm	36	51.80	17.48					0.004 *	
A				10.35 *	12.49	3.44	2.58 *		* VA AB
B				14.60 *	19.30	18.97	17.09		* VS AC
C				18.19	11.54	3.12	5.91 *		
% Vs	36	41.79	16.63					0.02 *	* VA AB
A				2.39 *	9.78 *	3.58 *	0.45 *		* VT AC
B				10.71 *	14.91	16.68	14.17		* VK AC
C				20.04	8.86 *	2.99 *	4.95 *		* VS AC

Note:* Value p <0. 05: statistically significant; **: statistically not significant; ANOVA

Table 2. Fraction of volume and void distribution (φ and SD).

Group Parameter	n	Mean	SD	SD				P	Interpretation
				VA	VT	VK	VS		
VOI (mm^3)	36	6:09	4.93					-	-
A				1:36	2.99	10.61	14.96		
B				1:12	1.94	6:19	9:16		
C				1:83	3.98	6:55	12:36		
(Φ) (%)	36	6:40						0:52	
A			10:50	9:54	2.71	0:44	2:29		**
B				7.63	4.99	2:49	2:93		
C				31.82	6.85	1:44	9:05		
(φc) (%)	36	0:41	0.95					0:52	**
A				0:03	0:38	0:29	0:30		
B				0:01	0:03	1:00	2:16		
C				0:08	0:05	0:38	0:24		
(φo) (%)	36	6:13	10:56					0:52	**
A				7.68	1.65	0.81	1.99		
B				10.70	4.63	2.90	5:00		
C				22.80	6:24	1:55	7.62		
SD (mm-1)	36	5.75	1.94					0.0001 *	* VT BC
A				8.75	5.62	3:47	4:12		
B				8.63	6.75 *	4.96	5.83		
C				7:07	5:05 *	4:22	4:47		

a significant difference between carrier-based thermoplastic condensation techniques compared with warm lateral condensation techniques ($p < 0.05$). The results of volume and void distribution showed no significant difference between condensation technique thermoplastic carrier-based and warm lateral condensation techniques in either the apical third, middle third, coronal third, or along the root canal (p 0.05).

The results of t-test analysis in Table 3 show the significantly differences of sealing abilit between thermoplastic carrier-based condensation technique and warm lateral condensation in the volume of filling material and the difference was very significant for the sealer volume in the apical third. The results show a very significant differences of sealing ability of the carrier-based thermoplastic condensation technique for the volume of filling and sealer compared to the cold lateral condensation technique along the root canal ($p <0.01$), while the void distribution show significant difference between the warm lateral condensation technique and cold lateral condensation in the middle third of the root canal ($p <0.05$).

Figure 4 shows the images of root canal filling volume in the form of 3D visual images of various pieces taken at random representing each technique. Based on the picture can be seen that the thermoplastic carrier-based condensation technique (a) had a maximal volume of obturation material including gutta percha and carrier with minimal volume sealer compared with warm lateral condensation and cold lateral condensation. Warm lateral condensation technique (b) show more homogenous volume of gutta percha with less sealer, and greater distribution of voids in the middle third of the root canal. The cold lateral condensation technique (c) show non homogeneous mass of gutta percha accompanied by a large volume of sealer and volume and void distribution that are spread along the root canal, especially voids that are related to the walls of the root canal. Carrier-

Table 3. T-Test.

Parameter	Mean	SD	p	T-test	Interpretation
% V fm	51.80				
VA A		10.35		0.03	* 1
B		14.60	0.004		
VS A		2.58		0.01	* 2
C		5.91			
% Vs	41.79				
VS A		2.39		0.01	* 2
B		10.71			
VT A		9.78		0.05	* 1
C		8.86	0.02		
VK A		3.58		0.01	* 2
C		2.99			
VS A		0.45		0.01	* 2
C		4.95			
SD	5.75				
VT B		0.69	0.0001	0.04	* 1
C		0.65			

Note:* 1 Value p <0. 05: significant difference; * 2 Value p <0. 01: the difference is very significant; T-test

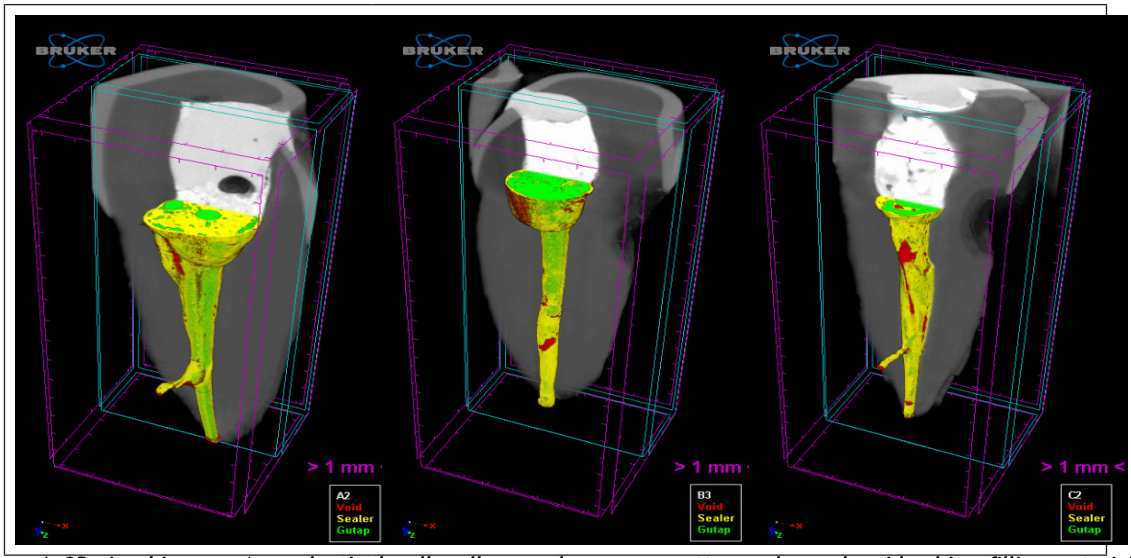

Figure 4. 3D visual images: (grey:dentinal wall; yellow: sealer; green: gutta-percha; red: void, white: filling material)

based thermoplastic condensation techniques and cold lateral condensation techniques show the sealer penetration reaching the lateral root canal in the apical third part of the root canal.

DISCUSSION

The results of sealing ability obturation between carrier-based thermoplastic techniques and warm lateral condensation techniques in this study indicate that there is no obturation technique that is free of void. It is confirmed by previous study by Gad et al[19], that showed none of root canal filled teeth gap-free and adequate seal cannot be measured by void percentage because it is depend on the sealer used in obturation. The results of this study also showed that the average volume of void in the apical third was greater than the middle third and coronal third in all obturation techniques studied (Table 2), is according to study of Silva et al[20], which found that the irregular anatomy of root canal system, including lateral root canals, accessories, isthmus, including ramification and apical foramen in apical third region affect the smear layer and debris cleaning process of the root dentinal wall thereby reducing the adaptation of obturation material to the root canal wall.[20, 21]

The incidence of void in study of Keles et al[11], also showed that obturation is affected by many factors, including the anatomical configuration of the root canal system, the quality of root canal preparation, consistency and volume of sealer, experience of operator, and the techniques.[11] The same was found by Huang et al[21], that the cleanliness of the root canal wall of the smear layer can inhibit the bonding and penetration of filling material into the dentinal tubules so that it affects the adaptation of gutta percha and sealers, especially to the density and diameter of the dentinal tubules from apical to coronal.[13, 21]

Micro-CT is used as a method to analyse the quality of obturation that can be done quickly, non invasive, and non-destructive and produces high resolution images from micrometers to nanometers.[6,18,22,23] Three dimensional visual images (Figure 3a) also show that the carrier-based thermoplastic condensation technique and the cold lateral condensation technique (Figure 3b) have a penetration capacity of obturation material through the lateral root canal. Similar results were obtained from several studies of the sealing ability obturation Gutta Core system, including study of Fragachan et al [23], obtained that Gutta Core have the most favourable volume and depth of obturation compared to other techniques were tested due to flow warm gutta percha that facilitate diffusion of gutta percha material and sealers to fill isthmus, lateral and accesories canals and produce better quality obturation.[23] Celikten et al[24] also found that thermoplastic carrier-based condensation technique has a good adaptation, which is achieved by utilizing the homogenous mass of warm gutta percha and resulting less voids.[24] Furthermore, Qassab et al[24], found that the Gutta Core system forms a homogeneous mass with the highest percentage filling material volume and lower sealer volume with less voids so that it adapts well in the root canal. Study of Yanpiset et al obtained similar results and relate its flow capacity of sealer calcium silicate-based or bio ceramics are very good and that the hydraulic pressure while placement of gutta percha with a layer of thin sealer enhances the sealer distribution and penetration reach the dentinal tubules and improve sealing ability obturation.[14]

The results showed a significant difference of fraction of filling material volume and volume of sealer between the carrier-based thermoplastic condensation technique and warm lateral condensation technique. Root canal obturation should utilize more volume gutta percha filling material and minimizing the volume of sealer. According to Yanpiset et al[14], the use of a thin sealer layer can reduce the risk of leakage associated with shrinkage or sealer decomposition over time thereby separate the bond between the filling material and the root canal wall which causes leakage. Keles et al[12], found that the void of obturation in his research was related to the polymerization of epoxy resin shrinkage sealer sealers used.

The result of void characteristics based on closed porosity in this study indicate that the largest volume is in the warm lateral condensation technique along the root canal, while the smallest volume is in the carrier-based thermoplastic technique in the apical third. Void are isolated

or internal void are considered not significantly affect the quality of the obturation compared to the void that is connected with the canal walls. The same results were obtained in the study of Obeidat et al[17], that the warm lateral condensation technique produces large internal void, especially in the two-thirds coronal portion that is connected with air trapping when between gutta-percha during heating. Obeidat found that this void does not greatly affect the quality of endodontic treatment because it does not support the growth of microorganisms, but according to Asheibi et al[17,24], the gap can be a nutritional channel for microorganisms to initiate or continue the inflammatory process.

The results of the open porosity assessment show that the warm lateral condensation technique has a greater percentage of external void than the carrier-based thermoplastic condensation technique, and the cold lateral condensation technique has the largest percentage of external void along the root canal. Asheibi et al[26], found that voids that are connected with periradicular tissue can become a pathway for microorganisms to obtain nutritional intake so that it affects the results of root canal treatment.The results of this study are similar with study by Naseri et al[27], that connecting the use of spreaders while condensation can make spacebetween the bond of gutta percha and sealer, and the use of large volume sealers allow resorption and create void and gaps.[27] The same thing is found by Qassab et al[25], that the condensation procedure using a spreader runs the risk of a gap between the main gutta percha, gutaa percha accessories and root canal wall.

Micro-CT devices such using in this study not only can see the characteristics of open or isolated voids, but also the size, location and surface of void.[14] The warm lateral condensation technique has a tendency to form and distribute complexvoidcomparedtothethermoplasticcarrier-based condensation technique as shown in the graphic of total porosity (Figure 2). The statistical analysis of surface density shows a significant difference in sealing ability between the warm lateral condensation technique and cold lateral condensation technique in the middle third of the root canal. The results are related to the use of heat carriers (SystemB, SybronEndo, USA) which are considered to affect the physical characteristics of thermoplastic gutta percha and the setting time of the sealer.[16.27]

The selection of temperature, binding point and duration of heating in accordance with the recommendations of Buchanan S as a safety consideration in thermoplastic techniques is at a temperature of 200° C and not more than 4 seconds.[16] Study of Marroquin et al found that contact or binding point when applying heat carrier and gutta- percha is 1-2 mm of working length. This point allows the filling of gutta-percha to form and reach apical compaction.[28] Qu et al used a binding point of 3-5 mm from the working length at a temperature of 200° C for a duration of 2 seconds in his study which showed a change in the plasticity of gutta percha reaching 1 to 2.1 mm towards the apical, thus affecting the sealing ability of filling root canal in the apical third.[16]

The results of this study indicate that carrier-based thermoplastic condensation techniques do not have better sealing abilities along the root canal than warm lateral condensation techniques and cold lateral condensation techniques. This result can occur due to several obstacles and limitations in research, including tooth selection, biomechanical preparation techniques and the process of testing samples that require time. According to Asheibi et al[26], random use of maxillary anterior dental samples without limiting the sample size in in vitro studies will affect the assessment of obtaining ability obturation associated with anatomical variation of root canals between individuals. Research Samadi et al[29], used maxillary incisor dental samples to avoid the possibility of root canal irregularity. Research conducted by Gencoglu et al choose to use samples of resin blocks to eliminate the effects of instrumentation that could interfere variables.[20] According to Huang et al, Micro-CT has limitations in analyzing the smear layer and debris in the dentinal tubules so that its research combines with SEM to support the examination of obtaining ability obturation.[13]

Based on the results of research and literature search, it could be known that the sealing ability of root canal obturation is determined from the adaptation of gutta percha filling and sealers to the root canal wall from apical to coronal.

CONCLUSION

There is no obturation technique with void free, and the carrier-based thermoplastic condensation technique have the lowest void percentage compared to warm lateral and cold condensation techniques in each apical third, middle third, coronal third, and along the root canal. Carrier-based thermoplastic condensation techniques do not have better sealing abilities than other obturation techniques.

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