Original Article

Comparative CBCT Assessment of Obturation Quality in Different Obturation Techniques

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Abstract

Introduction: Different techniques and materials have been introduced over time to improve the quality of root canal treatment. This study aimed to compare the quality of root canal obturation using three root canal obturation techniques based on the existing void using cone beam computed tomography imaging techniques. **Methods:** Thirty-three single canal teeth were selected and the root canals were prepared. The roots were obturated with single-cone, lateral compaction with cold gutta-percha, and vertical compaction techniques. Afterward, the roots were scanned, and the presence of voids in the 1-, 3-, 5-, and 7-mm sections of the root apex was investigated, and then the area and volume of voids were calculated by Mimics 10.01 software. **Results:** The highest percentage of voids presence in all groups was detected in the 7-mm section of the apex (60.6%) , while the lowest percentage was found in the 1-mm section of the apex (12.1%). **Conclusion:** There was no significant difference between the three techniques evaluated in this study in terms of void size, void volume, and obturation quality. Voids were present in all samples. Considering the technique used to obturate the root canals, voids were different in terms of shape and volume.

Keywords: Bioceramic sealer, CBCT, Lateral compaction, TotalFill, Vertical compaction

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Introduction

Root canal obturation aims to create an appropriate seal after chemical and mechanical preparation to prevent re-infection, leave no spaces for the proliferation of bacteria and accelerate periapical tissue healing. The purpose of canal filling techniques is to maximize the use of gutta-percha and reduce the thickness of the sealer to minimize microleakage after setting of the sealer is completed (1, 2).

Root canal obturation should prevent the oral fluids containing bacteria and the produced subtances from leaking into the root canal and reaching the periodontium through the root canal; it should also inhibit the residual bacteria enclosed in the root canal from exiting and proliferating. Therefore, the quality of root canal obturation can be improved by minimizing the remaining voids and spaces after obturating the root canal (3).

Different techniques have been introduced to obturate and seal the root canals, among which the techniques of lateral compaction with cold gutta-percha, single-cone, and vertical compaction with warm gutta-percha can be mentioned. Lateral compaction with cold gutta-percha technique is used because of its high level of safety, cost-effectiveness and satisfactory clinical results in endodontic treatment (2).

In order to increase the reduce the required chairtime and maximize the success rates of single-cone techniques, recently, the EndoSequence bioceramic sealer, known as TotalFill (FKG Dentire SA, La Chaux-de-Fonds, Switzerland), has been introduced with a biochemical base, whose inorganic ingredients include zirconium oxide, calcium silicates, monobasic calcium phosphate, calcium hydroxide, filler, and water-free condensing agents**.** This biochemical sealer is pre-mixed and ready to use. It is injectable, radiopaque and in the form of a hydrophilic paste. The process of starting and completing its setting is carried out using the moisture in the dentinal tubules. This time varies from 4 h to more than 10 h in a dry environment (4).

According to the results of a recent study by Madhuri et al., the EndoSequence bioceramic sealer has the highest bonding strength among “all” sealers, such as mineral trioxide aggregate (MTA)-based sealers (5). Moreover, according to the findings of a study by Polineni et al., this sealer has better marginal adaptation than MTA-based sealers (6).

Another technique that increases the quality of root canal obturation is vertical compaction with warm gutta-percha. Warmed gutta-percha and different sizes of plugger are used in this technique. Better adaptation to root canal walls and the absence of voids is the main advantage of using warm gutta-percha (7). This technique requires the insertion of the plugger up to 2-3 mm of the working length, which can increase the risk of root fracture by creating vertical and lateral stresses (7).

Previously conducted studies have also stated that the vertical compaction technique with warm gutta-percha tends to results in significantly smaller voids, compared to that in the lateral compaction with cold gutta-percha and single-cone techniques. Therefore, this method is considered the best way to obturate the root canal in terms of the minimum void size (1, 8, 9).

Voids in all the sections of the root canal, including the apical and coronal, can create paths to increase leakage, allowing the growth of bacteria and re-infection, necessitating retreatment. Voids that spread throughout the root canal increase the likelihood of the need for retreatment. According to the existing literature, the probability of creating a void in the obturated root canal, as well as the mismatch of the canal filling materials with the root canal wall, is higher in the lateral compaction technique, while in the vertical compaction method, there is a better adaptation, with lower odds of producing voids (10).

An appropriate way to obtain a 3D image of the root canal is the use of the computed tomography (CT) scan technique; however, due to its high cost and high dose of radiation, it is not routinely used in endodontic practice (10).

Several methods, such as cross-sectional observation or leakage tests, are used in the laboratory to determine the degree of adaptation of root canal obturation materials. In cross-sectional observations, an optical or electron microscope is utilized. An optical microscope is used primarily to report the outcomes of canal filling processes and evaluate new products and therapeutic methods. An electron microscope is employed to evaluate the quality of root canal obturation, investigating the surface between the filling material and the root canal wall (11)**.**

Following the development of the use of microtomography, which is a non-destructive method compared to other methods, the virtual components of the root sections can be easily achieved by a 3D image. Cone beam computed tomography images (CBCT) is a 3D imaging tool with such features as high precision and no destruction of the specimens. It covers the limitations of other methods as well. Cone beam computed tomography images can provide the best contrast to detect and distinguish between the root canal walls and the filling materials (11, 12). Therefore, in this study, CBCT was preferred over cross-sectional observation methods to investigate the sections with low spacing to prevent the destruction of specimens and measure void volumes.

Considering the importance of obturating the root canal with minimal residual space to prevent the proliferation of bacteria and leakage, three conventional methods of endodontic treatments were selected to investigate the quality of root canal obturation in this study. The performance of the newly supplied TotalFill sealer in the single-cone technique was also studied.

Materials and Methods

The sample size was determined at 11 cases in each group according to the results of similar studies and considering the mean percentages of voids in the single-cone and warm vertical compaction groups at 1.5±0.89 and 2.31±0.706, respectively, an alpha value of 0.05, and a study power of 80%; accordingly, a total of 33 samples were included in this study (13).

Tooth Preparation

Inclusion criteria were freshly extracted human teeth, single-canal with a curvature of <10° . A total of 33 teeth were selected according to the above listed inclusion criteria and were stored in in 10% formalin solution.

Teeth with immature apices, previous restorations, cervical caries, dental anomalies, root fractures, calcified root canals and previous endodontic treatment, were all excluded from the sample.

The teeth were shortened from the crown to a length of 18 mm, and the working length was precisely obtained by passing a #10 stainless steel K-file (Mani, Matsutain Seiaskusho Co., Tochigi-Keu, Japan) through the apex of the root and fixing at the tip of the apex. After finding and fixing the proper route of the canal with hand files, RaCe rotary files #30, 0.06 (FKG Dentire SA, La Chaux-de-Fonds, Switzerland) were used to clean and shape the root canals. During the preparation process and also during each obturation procedure, 1 mL of 5.25% sodium hypochlorite solution was used as an irrigation solution. At the end of the preparation, 5 mL of normal saline solution was used for final irrigation. The preparation of the root canals was carried out through the crown-down technique. In the end, all teeth were shaped with a #30 file with a 6% taper.

Root Canal Obturation

The teeth were randomly divided into three groups, namely A, B, and C. After drying the root canals, teeth in group A were obturated with the single-cone technique with coated gutta-percha (Sagimakgol-ro, Jungwon-gu, Seongnam-si, Gyeonggi-do, Korea) and TotalFill sealer (FKG Dentire SA, La Chaux-de-Fonds, Switzerland) without applying any accessory gutta-percha points.

Group B teeth were obturated using the lateral compaction technique with cold gutta-percha, choosing a #30 standard gutta-percha point as the master cone and AH26 sealer (Densely DeTrey GmbH, Konstanz, Germany). In this technique, after placing the master cone, a #25 or #30 spreader was placed, with the ability to be inserted up to 1.5 mm above the apex. After increasing the space in the apical third, a gutta-percha point with a smaller size, impregnated with sealer, was inserted into the created space, after which an appropriate size of the spreader with the highest penetration depth into the apical section was applied again, and an appropriate gutta-percha point was inserted into the created space. This process continued until the root canal was completely obturated so that the spreader could no longer penetrate into the root canal.

Group C teeth were obturated using the vertical compaction technique with warm gutta-percha and AH 26 sealer (Densely DeTrey GmbH, Konstanz, Germany). In this method, at first, an appropriate gutta-percha point, 2 mm shorter than the root canal working length, was selected as the master cone, and, after being coated with a sealer, was inserted into the root canal. A plugger with a small size was heated and measured to a length of 2 mm shorter than the canal length, through which gutta-percha was heated for 5 sec, and after cutting the gutta-percha, the remaining gutta-percha was compacted to the apical portion again. In the next step, after reinserting the gutta-percha, warming and compaction processes were carried out with a plugger which was one size larger. This process continued until the root canal was obturated completely by applying larger sizes of pluggers.

All teeth were kept at 37°C and 100% humidity for the complete setting of the sealer, followed by CBCT evaluations.

CBCT Imaging

A Newtom VGi CBCT machine (Verona, Italy) was used for imaging in the Department of Maxillofacial Radiology, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran. This device has a cone-shaped X-ray beam, a 1536×1920-pixel flat-panel detector, 360° rotation, a scan time of 18 sec, and a maximum kVp of 110. Initial and final reconstructions were carried out by NNT Viewer Version 2.21. The radiation conditions of the device were automatically adjusted. The images obtained from the samples were displayed on a 19-inch Phillips LCD monitor (190B) with a resolution of 1208×1024 and 32 bits, connected to a desktop computer.

In order to assess the results, at first, the presence or absence of voids was examined in axial sections at distances of 1, 3, 5, and 7 mm from the tooth apex. The void sizes, if any, were measured in square micrometers, and then the ratio of the voids in the whole area of the root canal in that section was calculated. In the next stage, the volume of the voids was calculated using Mimics 10.01 software.

Ethical Considerations

The present study was conducted on the teeth extracted for purposes other than those of this study. Appropriate steps were taken to observe the principles of environmental health and infection control. In addition, this study was approved by the Research Ethics Committee of Tabriz University of Medical Sciences, under code 1397.1066.

Results

Chi-squared test was used to investigate the relationship between the presence or absence of voids and the study groups. The significance level of the test was considered at 0.05. The results of the Chi-squared test (as presented in Table I and Figure 1) showed that:

Table I. Frequencies and percentages of the samples examined in terms of the group and the presence or absence of voids

Examined section	Examined group		No	Yes	P-value
1 mm	A (single-cone)	Frequency	11	0	0.011
		Percentage	100.0%	0.0%	
	B (lateral compaction)	Frequency	7	4	
		Percentage	63.6%	36.4%	
	C (vertical compaction)	Frequency	11	0	
		Percentage	100.0%	0.0%	
	Total	Frequency	29	4	
		Percentage	87.9%	12.1%	
3 mm	A (single-cone)	Frequency	7	4	0.077
		Percentage	63.6%	36.4%	
	B (lateral compaction)	Frequency	3	8	
		Percentage	27.3%	72.7%	
	C (vertical compaction)	Frequency	8	3	
		Percentage	72.7%	27.3%	
	Total	Frequency	18	15	
		Percentage	54.5%	45.5%	
5 mm	A (single-cone)	Frequency	3	8	0.231
		Percentage	27.3%	72.7%	
	B (lateral compaction)	Frequency	5	6	
		Percentage	45.5%	54.5%	
	C (vertical compaction)	Frequency	7	4	
		Percentage	63.6%	36.4%	
	Total	Frequency	15	18	
		Percentage	45.5%	54.5%	
7 mm	A (single-cone)	Frequency	5	6	0.602
		Percentage	45.5%	54.5%	
	B (lateral compaction)	Frequency	3	8	
		Percentage	27.3%	72.7%	
	C (vertical compaction)	Frequency	5	6	
		Percentage	45.5%	54.5%	
	Total	Frequency	13	20	

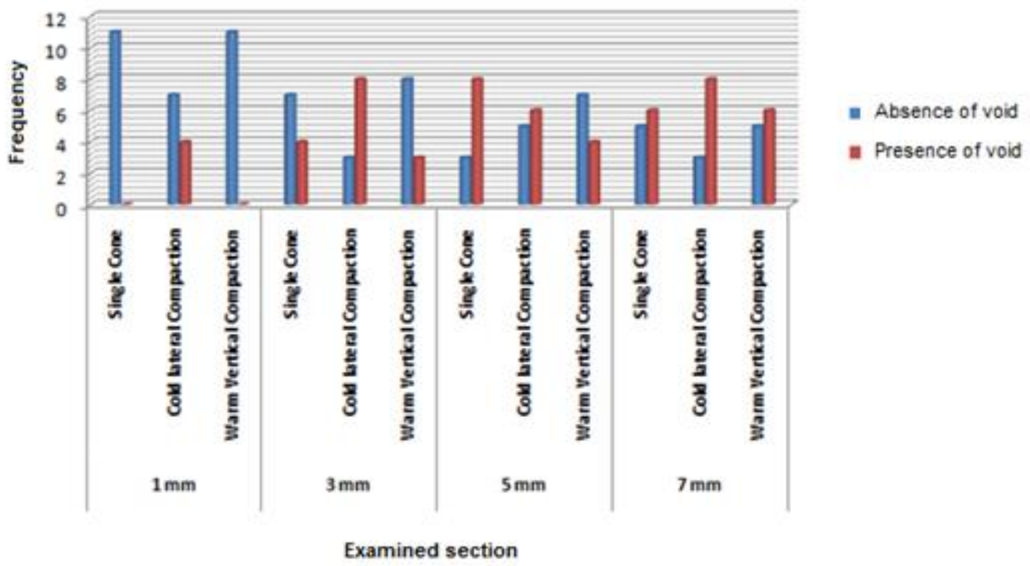

Figure 1. The frequency bar graph of the samples examined in terms of the group and the presence or absence of voids

A) There was a statistically significant relationship between the presence or absence of voids and the study groups in 1-mm sections (P<0.05).

B) There was no statistically significant relationship between the presence or absence of voids and the study groups in 3-mm, 5-mm, and 7-mm sections (P>0.05).

The means and standard deviations of the variable $\frac{\text{void area}}{\text{section area}}$ in the study groups are presented in Table II and Figure 2.

Table II. Means and standard deviations of the variable $\frac{\text{void area}}{\text{section area}}$ in the study groups

Examined section	Examined group	Mean	Standard deviation	P-value
1 mm	A (single-cone)	0.00000	0.000000	0.012*
	B (lateral compaction)	0.61818	0.872718	
	C (vertical compaction)	0.00000	0.000000	
3 mm	A (single-cone)	0.54364	0.761266	0.339*
	B (lateral compaction)	1.09818	0.950524	
	C (vertical compaction)	0.78636	1.192797	
5 mm	A (single-cone)	1.17273	0.931666	0.149*
	B (lateral compaction)	1.04727	1.067503	
	C (vertical compaction)	0.42182	0.639278	
7mm	A (single-cone)	0.87000	0.999630	0.253**
	B (lateral compaction)	1.90364	1.432943	
	C (vertical compaction)	1.36000	1.755545	

*Kruskal-Wallis H test; **One-way analysis of variance

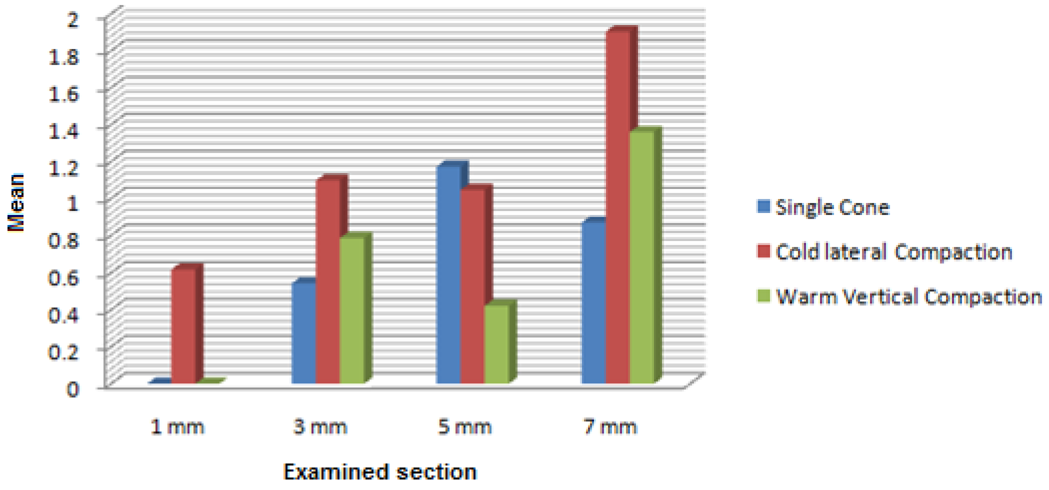

Figure 2. The mean column graph of the variable $\frac{\text{void area}}{\text{section area}}$ in the study groups

The results of this test showed that:

1. Distribution of the variable $\frac{\text{void area}}{\text{section area}}$ was not normal in 1-mm, 3-mm, and 5-mm sections (P<0.05).

2. Distribution of the variable $\frac{\text{void area}}{\text{section area}}$ was normal in the 7-mm section (P>0.05).

In 1-mm, 3-mm, and 5-mm sections, Kruskal-Wallis test was used to verify statistically significant differences between the mean ranks of the variable $\frac{\text{void area}}{\text{section area}}$ in the three study groups; in the 7-mm section, one-way ANOVA was used to verify a statistically significant difference between the means of the variable $\frac{\text{void area}}{\text{section area}}$ in the three study groups. The significance level of the test was considered at 0.05. The results of these tests are presented in Table II.

The results presented in Table II showed that:

There was a statistically significant difference between the mean rank of the variable $\frac{\text{void area}}{\text{section area}}$ in the three study groups (P<0.05).

However, post hoc test and Mann-Whitney U test were used to investigate which two groups had such differences. The significance level of the test was considered at 0.05. The results of this test are presented in Table III.

The results presented in Table III showed that:

Table III. Mann-Whitney U test results

The study groups	Mean rank	Total rank	P-value
A (single-cone)	9.50	104.50	0.032
B (lateral compaction)	13.50	148.50	
A (single-cone)	11.50	126.50	1
C (vertical compaction)	11.50	126.50	
B (lateral compaction)	13.50	148.50	0.032
C (vertical compaction)	9.50	104.50	

A) There was a statistically significant difference in the mean rank of the variable $\frac{\text{void area}}{\text{section area}}$ between groups A and B, with a lower mean rank in group A, compared to that in group B (P<0.05).

B) There was no statistically significant difference in the mean rank of the variable $\frac{\text{void area}}{\text{section area}}$ between groups A and C (P>0.05).

C) There was a statistically significant difference in the mean rank of the variable $\frac{\text{void area}}{\text{section area}}$ between groups C and B, with a lower mean rank in group C, compared to that in group B (P<0.05).

1) There was no statistically significant difference in the mean rank of the variable $\frac{\text{void area}}{\text{section area}}$ between the three study groups in 3-mm and 5-mm sections (P>0.05)

3) There was no statistically significant difference in the mean of the variable $\frac{\text{void area}}{\text{section area}}$ between the three study groups in the 7-mm section (P>0.05).

Discussion

Root canal obturation aims to create a proper seal after chemical and mechanical preparation to prevent re-infection, eliminate spaces for the proliferation of bacteria, and accelerate the periapical tissue healing process. The purpose of canal filling techniques is to maximize the use of gutta-percha points and reduce the thickness of the sealer to decrease the microleakage after the sealer has completely set (1, 2).

Voids in all sections of the root canal, including apical and coronal, can create pathways to increase leakage, allowing the growth of bacteria and re-infection, ultimately leading to root canal retreatment. Voids that spread throughout the root canal increase the odds of the need for retreatment. According to the available literature, the probability of creating a void in root canal fillings and a lack of adaptation of the root canal filling materials with the root canal wall are higher in the lateral compaction method, while in the vertical compaction method, better adaptation results with a lower probability of creating voids are obtained (7).

Various techniques and materials have been introduced over time to enhance the quality of root canal treatment, of which the three most common root canal filling techniques were used in this study. Additionally, the commonly used AH26 sealer was used for the two techniques of lateral compaction with cold gutta-percha and vertical compaction with warm gutta-percha, and the newly supplied TotalFill bioceramic sealer, along with the gutta-percha, was used for the single-cone technique.

In this study, after data collection, no significant relationship was found between the groups in terms of the presence and absence of voids in the 3-, 5-, and 7-mm sections. However, in the 1-mm sections, significant differences were observed between the groups. The groups with single-cone and vertical compaction with warm gutta-percha were superior to the group with lateral compaction with cold gutta-percha; however, no significant difference was found between the group with single-cone gutta-percha and the group with vertical compaction with warm gutta-percha. Concerning the percentage of the void area-to-canal area ratio and after testing the normality or abnormality of data distribution, the comparisons showed a significant difference in the percentages of the void area-to-canal area ratio in the 1-mm section between the study groups. The comparison of the mean ranks of the groups revealed that the mean rank of the groups with single-cone and vertical compaction with warm gutta-percha was less than that of the group with lateral compaction with cold gutta-percha. However, there was no statistically significant difference between the two groups with single-cone and vertical compaction techniques with warm gutta-percha.

Regarding the comparison of the volume of the voids, after testing the normality or abnormality of data distribution and their statistical comparison, a statistically significant difference was observed in the 1-mm section. Comparison of the mean rank of void volume between the study groups showed a significant difference in the volume of voids between single-cone and vertical compaction with warm gutta-percha techniques and lateral compaction with cold gutta-percha technique, while no statistically significant difference was found between the single-cone and vertical compaction with warm gutta-percha techniques. Considering the use of rotary files to prepare all the samples, which results in greater enlargement of the apical area compared to the use of hand files, the significant difference in the 1-mm sections could be attributed to the insufficient penetration of the spreader into some samples in the group with the lateral compaction and cold gutta-percha to create adequate space for gutta-percha and sealer, resulting in voids 1 mm away from the apex.

The results of this study are consistent with those of a study by Langwey et al., who examined void sizes in the apical section of the root in single-cone technique and vertical compaction technique with warm gutta-percha, showing that the percentage of voids was similar in the two methods with no significant difference between them (14).

Neohouse et al. compared root canal obturation in the apical section in curved canals, using two techniques of vertical compaction with warm gutta-percha and single-cone, the results of which indicating that there was very little difference or no difference between the two techniques and warm gutta-percha in terms of conformity, uniformity, and void size. However, these two techniques showed better results and used less sealer compared to the single-cone technique. The results of the aforementioned studies are different from those of the present study, which can be due to the use of curved canals and different root canal filling materials (15).

Wang Wei et al. investigated the size of the voids and the ability of the sealer to penetrate into the dentinal tubules in the vertical compaction with warm gutta-percha and single-cone techniques using bioceramic and AH Plus sealers. The results did not reveal any significant relationship between the applied obturation technique and the used sealer with the probability of creating voids and gaps in the root canal filling materials. However, regardless of the obturation methods, the bioceramic sealer demonstrated a significantly greater penetration rate into the dentinal tubules, in comparison to AH Plus sealer. Considering the bioactivity characteristics of the bioceramic sealer compared to the AH Plus sealer, a better filling quality can be expected. The results of the mentioned study are consistent with those of the present study. It can be pointed out that there was no significant difference between the single-cone technique using bioceramic sealer and the vertical compaction technique using AH Plus sealer in terms of the size of the formed voids (16).

Janani M et al. investigated root canal filling quality and periapical health using periapical, panoramic, and cone-beam computed tomography radiographic techniques.The result significant difference in the quality of root canal obturation was observed between periapical and panoramic radiographs with CBCT; however, no significant difference was observed between periapical and panoramic radiographs (17).

Conclusion

Under the limitations of this in vitro study, it can be concluded that there was no significant difference between the three techniques evaluated in this study in terms of void size, void volume, and obturation quality. Voids were present in all samples. Considering the technique used to obturate the root canals, voids were different in terms of shape and volume. The voids in the lateral compaction technique with cold gutta-percha were made in the form of narrow and long voids along the root, while using vertical compaction with either warm gutta-percha or single-cone, resulted in mostly spherical and polygonal voids. In the 1-mm section of the tooth apices and in terms of the presence of voids, the two techniques of vertical compaction with warm gutta-percha and single-cone showed significantly fewer voids than the lateral compaction with cold gutta-percha technique; therefore, it can be concluded that the TotalFill bioceramic sealer system, with its special gutta-percha, could provide better quality in single-cone technique and similar to vertical compaction with warm gutta-percha technique. Due to the high speed and convenience of root canal treatment, the single-cone technique has gained much attention.

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Conflicts of Interest

There is no conflict of interest.

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