Cervical and Incisal Marginal Discrepancy in Ceramic Laminate Veneering Materials: A SEM Analysis

Abstract

Context: Marginal discrepancy influenced by the choice of processing material used for the ceramic laminate veneers needs to be explored further for better clinical application. **Aims:** This study aimed to evaluate the amount of cervical and incisal marginal discrepancy associated with different ceramic laminate veneering materials. **Settings and Design:** This was an experimental, single-blinded, *in vitro* trial. **Subjects and Methods:** Ten central incisors were prepared for laminate veneers with 2 mm uniform reduction and heavy chamfer finish line. Ceramic laminate veneers fabricated over the prepared teeth using four different processing materials were categorized into four groups as Group I - aluminous porcelain veneers, Group II - lithium disilicate ceramic veneers, Group III - lithium disilicate-leucite-based veneers, Group IV - zirconia-based ceramic veneers. The cervical and incisal marginal discrepancy was measured using a scanning electron microscope. **Statistical Analysis Used:** ANOVA and *post hoc* Tukey honest significant difference (HSD) tests were used for statistical analysis. **Results:** The cervical and incisal marginal discrepancy for four groups was Group I - 114.6 ± 4.3 µm, 132.5 ± 6.5 µm, Group II - 86.1 ± 6.3 µm, 105.4 ± 5.3 µm, Group III - 71.4 ± 4.4 µm, 91.3 ± 4.7 µm, and Group IV - 123.1 ± 4.1 µm, 142.0 ± 5.4 µm. ANOVA and *post hoc* Tukey HSD tests observed a statistically significant difference between the four test specimens with regard to cervical marginal discrepancy. The cervical and incisal marginal discrepancy scored $F = 243.408$, $P < 0.001$ and $F = 180.844$, $P < 0.001$, respectively. **Conclusion:** This study concluded veneers fabricated using leucite reinforced lithium disilicate exhibited the least marginal discrepancy followed by lithium disilicate ceramic, aluminous porcelain, and zirconia-based ceramics. The marginal discrepancy was more in the incisal region than in the cervical region in all the groups.

Keywords: *Ceramic laminate veneers, cervical discrepancy, computer-aided design/computer-aided manufacturing ceramics, incisal discrepancy, marginal discrepancy, pressable ceramics*

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Introduction

All-ceramic laminate veneer restorations have rendered excellent service in restoring discolored teeth.[1] All-ceramic restorations offer superior biocompatibility than the composite resin and porcelain-fused-to-metal restorations. However, the marginal fit of all-ceramic restorations does not match that of cast restorations, which offer better marginal adaptability.[2] The marginal fit is of paramount importance for long-term success of all-ceramic restorations. Discrepancy in marginal fit facilitates salivary infiltration and microleakage resulting in dissolution of the luting cement, thus increasing the susceptibility to caries, eventually leading to pulpal damage.[3] Marginal discrepancy also inflicts severe sensitivity due to the exposure of dentinal tubules and favors collection of plaque and food debris around the exposed margins which subsequently initiates periodontal breakdown in abutment teeth.[4] Various factors such as type of finish lines, die spacing, choice of restorative materials, processing technique, cementation procedures, and luting agents influence marginal fit.[5] The basic techniques used in all ceramic fabrications include powdered liquid glass base system, pressable glass base system, and computer-aided design/computer-aided manufacturing (CAD/CAM) system.[6]

Pressable ceramics are usually available as glass-ceramic ingots from the manufacturers. The ingots have a similar composition of powdered porcelain systems, but they have less porosity and increased crystalline content. The ingots are then heated to a high temperature

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where they transform into a highly viscous liquid, and are then pressed in a slow manner into the formed mold. IPS Empress® and IPS Empress 2® (Ivoclar Vivadent) are examples of materials fabricated by hot pressing technique.

CAD/CAM[7] technique offers a great advantage over conventional processing techniques by eliminating clinical steps in impression making and laboratory steps including cast and model pouring, articulation, die sectioning, casting, and subsequent layering, thus conserving time and workforce.[8] Computer-aided machinable ceramics are available as prefabricated ceramic glass ingots. They are shaped by equipment that are controlled by the computer. After the tooth preparation, an optical impression is made by a special scanner. The image is then transferred to the software system which then designs the restoration and transfers the data to the computer-controlled milling machine that shapes the ceramic block according to the desired configuration.[9]

Zirconium dioxide-based CAD/CAM ceramics have improved mechanical properties. They have high flexural strength (750–>1000 MPa) when compared to other dental ceramics.[10] Yttrium oxide is added to zirconia to stabilize the tetragonal phase at room temperature to prevent the crack propagation in the ceramic.[11] Zirconium oxide ceramics are indicated for the fabrication of crown and bridges and also for individual implant abutments.[10] The cores have high radiopacity which is very useful in the evaluation of marginal integrity.[12] Zirconia has a similar tooth color, but if additional translucency is needed, other ceramic materials should be considered.[11]

The glass-, alumina-, and zirconia-based ceramics[13] exhibit varying degrees of strength, esthetics, and function. However, the amount of marginal discrepancy exhibited by these materials is not reported clearly in literature and hence needed to be investigated further in detail. Hence, this study was formulated to evaluate and estimate the amount of marginal discrepancy for all-ceramic laminate veneering materials.

Aim

This study aimed to evaluate the amount of cervical and incisal marginal discrepancy associated with different ceramic laminate veneering materials.

Objectives

- To estimate the amount of cervical marginal discrepancy associated with different ceramic laminate veneering materials
- To estimate the amount of incisal marginal discrepancy associated with different ceramic laminate veneering materials
- To compare and evaluate the amount of cervical and incisal marginal discrepancy associated with different ceramic laminate veneering materials.

Null hypothesis H0

There is no significant difference in marginal discrepancy between four experimental ceramic laminate veneering materials by scanning electron microscope (SEM) analysis.

Alternate hypothesis Ha

There is a significant difference in marginal discrepancy between four experimental ceramic laminate veneering materials by SEM analysis.

Subjects and Methods

Extracted human maxillary central incisors satisfying the following criteria were selected for the study. The teeth included in the study were extracted due to surgical purposes, aggressive periodontitis, juvenile periodontitis, fenestrations, and dehiscence. The teeth excluded from the study were carious, nonvital, attrited abraded, eroded, endodontically treated, partially fractured, and already prepared teeth. The selected teeth were stored in 10% formalin solution and cleaned thoroughly of all deposits and soft tissue debris with a bristle brush and nonfluoridated pumice paste. Putty dies measuring 10 mm × 10 mm were prepared and lubricated with petroleum jelly and a smooth mix of self-cure acrylic was mixed in a vibrator and poured into the molds. The selected ten central incisors were embedded in an acrylic block, 10 mm × 10 mm in dimension. The clinical crown was exposed at the cementoenamel junction. The exposed clinical crowns were subjected to laminate veneer preparation. Depth orientation grooves were placed on the cervico- and incisolabial portions of the crown, and a uniform reduction of 2 mm was accomplished and a heavy chamfer finish line was established. Ceramic laminate veneers were fabricated using four different processing materials over the prepared teeth. The experimental materials used in the study were as follows:

Group I

Ceramic laminate veneers fabricated using aluminous porcelain (Sirona - Dentsply, New York, Pennsylvania, USA) fabricated by CAD/CAM milling system.

Group II

Ceramic laminate veneers fabricated using lithium disilicate-based ceramics (e.max Press - Ivlocar Vivadent, Liechtenstein) fabricated using pressable ceramic processing system.

Group III

Ceramic laminate veneers fabricated using lithium disilicate-leucite-based ceramics (IPS Empress 2, Ivlocar Vivadent, Liechtenstein) fabricated using pressable ceramic processing system.

Group IV

Ceramic laminate veneers fabricated using zirconia-based ceramics (ZirkonZahn, Amann Girrbach, America Charlotte, North Carolina, USA) fabricated using CAD/CAM milling system.

Fabrication of Sirona and zirconia laminate

The prepared teeth were subjected to optical impression by a special scanner called the Bluecam camera of CEREC CAD/CAM system. A thin layer of contrast powder was applied on top of the prepared tooth surface before the optical impression. The CEREC Bluecam was gradually moved over the relevant area to capture the image of the prepared surface. As soon as the teeth had been scanned, the data were assembled into a graphic depiction of the laminate preparation. The computer graphic design program was then used to trace the margins and anatomy of the prepared surface. The software proposed the design of laminate based on the recorded information. The program then processed the information from the completed laminate design, the prefabricated Sirona ceramic block was inserted into the milling chamber, and the laminate was milled.

Fabrication of e.max and Empress laminates

An impression was made from the prepared teeth surface which was used to pour a master cast which replicated the prepared teeth. Die-hardening agent was applied to the prepared teeth surface of the cast to protect it from abrasion. Die relief agent was painted on the preparation portion of the die, 0.5 mm short of the finish line,[14] following which wax was added by heating the PKT instrument in the bunsen flame. The laminate coping was thus fabricated and sprue was attached to the coping.[15] The wax pattern was then invested for casting. Heated e.max ceramic ingot was pressed through a heated tube into the mold, cooled, and hardened to the shape of the mold, and later recovered after cooling.[16] Hot pressing occurred over a 45 min at a high temperature and produced the ceramic substructure. Then it was stained, glazed, or coated by veneering porcelain.

Tescan (scanning electron microscope)

The test specimen was mounted over the prepared teeth that were held in position using the resin jig under the SEM (TESCAN Model Type: VEGA3, Czech Republic, Czechoslovakia) with a magnification of ×100,000 and the marginal discrepancy was estimated. The marginal discrepancy was observed in two dimensions, cervical and incisal.

VEGA3 is a system intended for both low and high vacuum operations for more rapid image acquisition, with an ultra-rapid scanning system which compensates for static and dynamic image aberrations or scripting for user-defined application purposes. Also, by means of powerful turbo-molecular and rotary vacuum pumps, optimum operating vacuum condition can be reached within few minutes.[17] VEGA3 microscopes can be configured in four chamber sizes, namely, SB, LM, XM, and GM. These chambers are fixed with a variety of ports and are designed with optimal geometry for EDX, WDX, and EBSD analyses.[18]

Evaluation of outcome measure marginal discrepancy

Each laminate was placed on the teeth and stabilized using an acrylic jig following which teeth samples were mounted rigidly on the specimen holder called a specimen stub using a conductive adhesive. Since the teeth sample is a nonconductor, it was coated with an ultrathin coating of electrically conducting material gold, deposited on the sample by low-vacuum sputter coating. SEM sample chamber will be under vacuum. After placing the samples and stabilizing with the adhesive, the door is closed by pushing the door back into the chamber. Then, the internal pressure inside the chamber was brought to about 10^−6 torr. After this, the image of the sample was measured with a magnification of ×100,000 and the marginal discrepancy was estimated.[18] Cervical marginal discrepancy is the distance between the axial tooth surface and the intaglio surface of the restoration in the most cervicoapical region, expressed as microns [Figure 1]. Incisal marginal discrepancy is the measurement of the space present between the tip of the restoration to the incisal edge, expressed as microns [Figure 2].

Results

Table 1 shows the means of cervical and incisal marginal discrepancy of Group I - aluminous porcelain (Sirona) 114.6 ± 4.3 μm and 132.5 ± 6.5 μm, Group II - lithium disilicate-based ceramics (e.max Press) - 86.1 ± 6.3 μm and 105.4 ± 5.3 μm, Group III - lithium disilicate-leucite-based ceramics (IPS Empress 2) - 71.4 ± 4.4 μm and 91.3 ± 4.7 μm, and Group IV – zirconia-based ceramics (ZirkonZahn) - 123.1 ± 4.1 μm and 142.0 ± 5.4 μm. Table 2 shows ANOVA for comparison of means of cervical marginal discrepancy and the inference; there is a statistically significant difference between the four test specimens with regard to cervical marginal discrepancy (F = 243.408, P < 0.001). Table 3 shows ANOVA for comparison of means of incisal marginal discrepancy and the inference; there is a statistically significant difference between

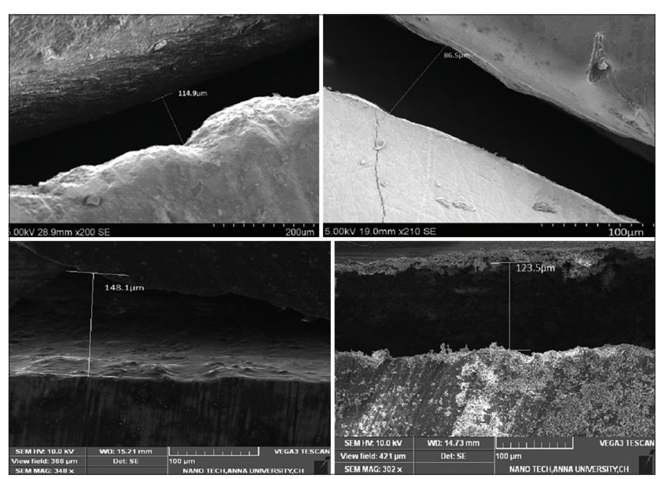

Figure 1: Cervical marginal discrepancy of the experimental groups

Table 1: Means of cervical and incisal marginal discrepancy

Variables	Experimental groups	*n*	Mean (µm)	SD (µm)
Cervical marginal discrepancy	Group I - Aluminous porcelain (Sirona)	10	115.9	1.2
	Group II - Lithium disilicate-based ceramics (e.max press)	10	87.4	0.75
	Group III - Lithium disilicate-leucite-based ceramics (IPS Empress 2)	10	71.7	0.89
	Group IV - Zirconia-based ceramics (ZirkonZahn)	10	124.5	1.07
Incisal marginal discrepancy	Group I - Aluminous porcelain (Sirona)	10	132.3	0.86
	Group II - Lithium disilicate-based ceramics (e.max press)	10	106.2	1.0
	Group III - Lithium disilicate-leucite-based ceramics (IPS Empress 2)	10	91.2	0.57
	Group IV - Zirconia-based ceramics (ZirkonZahn)	10	142.7	1.25

SD: Standard deviation

Table 2: ANOVA for comparison of means of cervical marginal discrepancy

	Sum of squares	df	Mean square	*F*	Significant
Between groups	18,130.535	3	6043.512	6067.952	0.001
Within groups	35.855	36	0.996		
Total	18,166.390	39			

Table 3: ANOVA for comparison of means of incisal marginal discrepancy

	Sum of squares	df	Mean square	*F*	Significant
Between groups	16,727.663	3	5575.888	6094.421	0.001
Within groups	32.937	36	0.915		
Total	16,760.600	39			

the four test specimens with regard to incisal marginal discrepancy ($F = 180.844$, $P < 0.001$). Table 4 shows Tukey honest significant difference (HSD) *post hoc* test for multiple comparisons for cervical marginal discrepancy that there was a high statistical difference between the four experimental groups ($P < 0.001$). Table 5 shows Tukey HSD *post hoc* test for multiple comparison for incisal marginal discrepancy that there was a high statistical difference between the four experimental groups ($P < 0.001$).

Discussion

The results of the present study negated the null hypothesis, and a significant difference in marginal

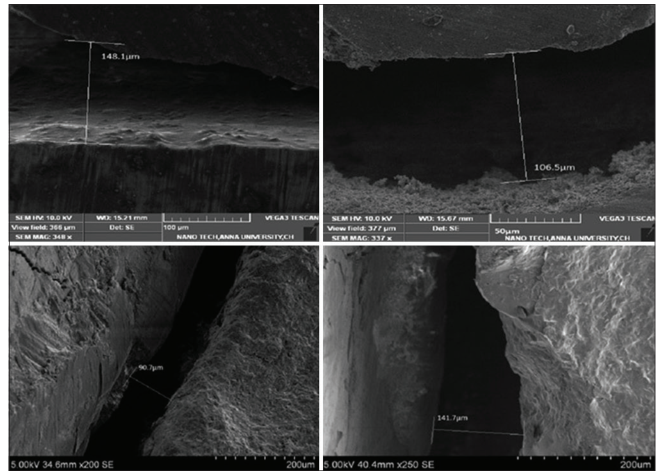

Figure 2: Incisal marginal discrepancy of the experimental groups

discrepancy was observed between the various laminate veneering materials and processing techniques. Various techniques have been used for the determination of *in vitro* microleakage. These techniques include the use of microbes, compressed air, chemical and radioactive tracers, electrochemical investigations, SEM, and the use of dye penetration.[19] El-Badrawy, Wafa, *et al.* suggested that the use of radioisotopes provides estimation of finer detail in leakage studies as the smaller ions measure up to 40 nm compared with the smaller dye particles (120 nm). Therefore, autoradiography is still a qualitative and a sensitive technique for determining leakage.[20]

This study utilized the SEM to observe marginal discrepancy. The SEM used in this study, TESCAN (Model Type: VEGA3 Series: SBU, Czech Republic, Czechoslovakia) magnification ×100,000, is a high precision instrument which can accurately record the amount of discrepancy at various levels with remarkable precession.[17]

Sjögren[21] evaluated marginal and internal fit of four types of ceramic inlays – CEREC, Celay, Empress, and VITA In-Ceram Spinell after they had been luted on extracted premolars. The best internal fit was recorded for the Celay inlays, whereas the other systems showed no significant difference in the internal fit. Inokoshi *et al*., 1992,[22] studied the marginal accuracy of computer-machined porcelain inlays. Two types of mesio-occlusal-distal cavities in resin teeth were prepared with either sharp or rounded box corners. The distance in the occlusal and proximal marginal interface was accessed using a measuring microscope. The occlusal interfacial distance was 52 µ for both.

Nakamura *et al*., 2005,[23] evaluated the marginal and internal adaptation of all-ceramic crowns fabricated using the CAD/CAM system. A master die of maxillary first bicuspid was prepared, and experimental crowns were fabricated. Four conditions were simulated by combining two convergence angles (4° and 12°) of the abutment with two different luting space configurations (15 pm and 55 µm,

Table 4: Tukey honest significant difference *post hoc* test for multiple comparison for cervical marginal discrepancy

Multiple comparisons Dependent variable: Values Tukey HSD						
Groups (I)	**Groups (J)**	**Mean difference (I−J)**	**SE**	**Significant**	**95% CI**	
					Lower bound	**Upper bound**
1.00	2.00	28.55000*	0.44631	0.001	27.3480	29.7520
	3.00	44.22000*	0.44631	0.000	43.0180	45.4220
	4.00	−8.56000*	0.44631	0.000	−9.7620	−7.3580
2.00	1.00	−28.55000*	0.44631	0.000	−29.7520	−27.3480
	3.00	15.67000*	0.44631	0.000	14.4680	16.8720
	4.00	−37.11000*	0.44631	0.000	−38.3120	−35.9080
3.00	1.00	−44.22000*	0.44631	0.000	−45.4220	−43.0180
	2.00	−15.67000*	0.44631	0.000	−16.8720	−14.4680
	4.00	−52.78000*	0.44631	0.000	−53.9820	−51.5780
4.00	1.00	8.56000*	0.44631	0.000	7.3580	9.7620
	2.00	37.11000*	0.44631	0.000	35.9080	38.3120
	3.00	52.78000*	0.44631	0.000	51.5780	53.9820

SE: Standard error; CI: Confidence interval; HSD: Honest significant difference; *: Significant at level 0.001

Table 5: Tukey honest significant difference *post hoc* test for multiple comparison for incisal marginal discrepancy

Multiple comparisons Dependent variable: Values Tukey HSD						
Groups (I)	**Groups (J)**	**Mean difference (I−J)**	**SE**	**Significant**	**95% CI**	
					Lower bound	**Upper bound**
1.00	2.00	26.09000*	0.42777	0.001	24.9379	27.2421
	3.00	41.10000*	0.42777	0.000	39.9479	42.2521
	4.00	−10.42000*	0.42777	0.000	−11.5721	−9.2679
2.00	1.00	−26.09000*	0.42777	0.000	−27.2421	−24.9379
	3.00	15.01000*	0.42777	0.000	13.8579	16.1621
	4.00	−36.51000*	0.42777	0.000	−37.6621	−35.3579
3.00	1.00	−41.10000*	0.42777	0.000	−42.2521	−39.9479
	2.00	−15.01000*	0.42777	0.000	−16.1621	−13.8579
	4.00	−51.52000*	0.42777	0.000	−52.6721	−50.3679
4.00	1.00	10.42000*	0.42777	0.000	9.2679	11.5721
	2.00	36.51000*	0.42777	0.000	35.3579	37.6621
	3.00	51.52000*	0.42777	0.000	50.3679	52.6721

SE: Standard error; CI: Confidence interval; HSD: Honest significant difference; *: Significant at level 0.001

respectively). The results revealed that the experimental crowns showed a marginal gap of 42–56 pm. When the luting space setting was 15 µm, the internal gap was 85–88 pm; when the setting was 55 pm, the internal gap was 126–138 pm. The marginal gap for all experimental crowns met the clinically acceptable criteria.

Quintas *et al*.[24] have reported an increase in the marginal discrepancy following luting with resin cements. Borges *et al*.[25] also evaluated *in vitro* marginal fit of three all-ceramic crown systems before and after cementation and observed that both resin-modified glass ionomer and resin cements induce increase in marginal discrepancy. Rinke *et al*.[26] proposed a study to compare the marginal adaptation and fracture resistance of conventional and copy-milled In-Ceram crowns. The marginal accuracy of the copy-milled units ranged from 6 to 153 µm and that of the conventionally fabricated units ranged from 1 to 153 µm.

Sulaiman *et al*.[27] reported the mean marginal discrepancy of all-ceramic crowns was in descending order: In-Ceram (161 ± 46 µm), Procera (83 ± 41 µm), and IPS Empress (63 ± 46 µm). Both Procera and IPS Empress met the criterion for acceptable marginal discrepancy of 120 µm.

Beschnidt and Strub[28] reported that Empress staining technique crowns showed the smallest marginal gaps (median 47 µm), followed by the conventional In Ceram crowns (median 62 µm), and Empress veneer technique crowns (median 62 µm). Celay feldspathic crowns had marginal gap with a median of 78 µm.

Nakamura *et al.*[29] reported that the alumina cores fabricated had mean gaps of 30–40 µm at the margins on the labial and lingual sides, which was significantly smaller than the gaps produced by the conventional method (67–130 µm).

Suárez *et al.*[5] proposed a study to determine the influence of two finish line designs on the marginal accuracy of Procera AllCeram crowns. The marginal gap was present within the range of clinical acceptability.

Lee *et al.*[30] in their study found that internal gaps of conventional all-ceramic crowns were within the range of 123–154 µm. CEREC 3D crowns (109.5 + 4.7 µm) showed significantly larger gaps than the Procera System (copings 71.4 ± 5.3 µm, crowns 68.8 ± 6.9 µm).

The other factors which can influence marginal discrepancy in laminate veneers in clinical situations include influence of the luting cement, salivary pH, brushing technique, errors in tooth preparation, and oral hygiene maintenance.[31] Fluctuation in salivary pH, quantity of gingival crevicular fluid and plaque accumulation, and microbial colonization subsequently lead to dissolution of luting cement inducing microleakage and aggravating the existing marginal discrepancy. Resin cements by virtue of their chemical structure are more resistant to dissolution by water, beverages, saliva, and gingival crevicular fluid and offer better resistance to plaque accumulation and microbial colonization whereas other cements are prone to dissolution and subsequently secondary caries of the abutment could occur with time.[32] Resin cements have been modified to release fluoride to prevent secondary caries. Improper brushing technique and aggressive brushing techniques using powered electrical tooth brushes can damage the cervical enamel rods and thin edges of the laminate veneers in the cervical region and could facilitate additional marginal leakage. Compromised oral hygiene resulting in the accumulation of plaque and calculus induces inflammatory changes in the adjoining areas which lead to subsequent pathogenic microbial colonization; this also can play a major part in the marginal discrepancy of the veneers.[33] Insufficient tooth preparation in the cervical region may lead to overcontoured restorations which could cause maloverlap of the veneers and could increase marginal discrepancy. The clinical significance of this study supports the choice of veneers fabricated with pressable ceramic systems than the CAD/CAM-milled veneers. However, other factors such as availability, expertise with the materials, choice of the patient, and other clinical parameters such as the tooth in which the laminate veneers are prepared and the type of discoloration being treated, are needed to be carefully considered during choosing the veneers for restorative rehabilitation.

Conclusion

This study concluded that veneers fabricated using leucite-reinforced lithium disilicate exhibited the least marginal discrepancy followed by lithium disilicate ceramic, aluminous porcelain, and zirconia-based ceramics. The veneers fabricated using pressable ceramic processing systems exhibited less marginal discrepancy than the veneers fabricated using CAD/CAM milling technique. Cervical marginal discrepancy was observed to be lesser than the incisal marginal discrepancy in all the experimental groups.

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Conflicts of interest

There are no conflicts of interest.

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