Original Article

Comparison of the Translucency Parameters and Bond Strength of 5Y-ZP Zirconia, 3-YTZP Zirconia, and Lithium Disilicate

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Abstract

Background: E-max is a more aesthetic material than traditional zirconia. In addition, the bond strength of traditional zirconia with adhesive cements is lower. There are not enough studies on how the aesthetic values and bond strength of 5-YZP, the new generation zirconia, compare to e-max and traditional zirconia. Can 5-YZP be an alternative to e-max in terms of aesthetics and bond strength? **Aim:** The aim of the study is to compare the translucency property and bonding ability of 5y-zp zirconias with previous generation zirconias and lithium disilicate. **Materials and Methods:** Two types of zirconia Katana UT and Katana HT for measuring translucency values; and using a type of lithium disilicate IPS e.max CAD LT, three groups were formed (n = 10). Translucency specimens were fabricated (n = 10). Their L*a*b* values were measured against a black-and-white background with a spectrophotometer, and DE00 was calculated. To perform micro-shear tests, a cylinder design was made from zirconia and IPS e.max CAD blocks (n = 20). After the samples were aged by thermal cycle, the micro-shear test was applied to specimens cemented to teeth extracted with two different adhesive cement systems. **Results:** According to the results of one-way analysis of variance, a statistically significant difference was found between the translucency parameter (TP) values of the groups. According to Tukey's honestly significant difference (HSD) multiple comparisons, the values of the three groups are statistically different from each other. Although IPS e.max CAD group has the highest TP values, the Katana HT group has the lowest values. **Conclusion:** 5Y-PZ has a TP intermediate to those of 3Y-TZP and lithium disilicate. Long-term bond strength of 3Y-TZP and 5Y-ZP were similar to those of lithium disilicate. To be an alternative to glass ceramics in the anterior region, translucency and bond strength values need to be improved.

Keywords: *Lithium disilicate, micro-shear bond strength, zirconia*

Introduction

Lithium disilicate ceramics in all-ceramic systems have improved mechanical properties and great optical properties compared to conventional dental porcelains. Although lithium disilicate exhibits lower mechanical properties compared to zirconia, it is considered superior in terms of translucency.[1,2] However, despite the aesthetic advantage of glass ceramics, the demand for stronger ceramic restorations has increased. This situation has expanded the application areas of high-strength zirconia-based ceramics in dentistry.[3]

Zirconia is a metastable ceramic with monoclinic, tetragonal, and cubic crystalline phases. Pure zirconium is stable in its monoclinic phase at room temperature. However, in order for the zirconia used in dentistry to remain stable at room temperature, various metal oxides such as Ca (calcium), Mg (magnesium), Al (aluminum),

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Y (yttrium), or Ce (cerium) must be added. Traditionally, it is stabilized by adding 3 mol% yttrium. Thus, tetragonal or cubic crystals of zirconia can remain thermodynamically metastable at room temperature.[4,5]

Although 3-YTZP ceramics have excellent mechanical properties, they have low translucency.[6] For yttria-stabilized zirconia, the cubic phase content, which is controlled by both the sintering temperature and the yttria content, can be modified to regulate the translucency features. In general, the cubic content and translucency increase as the yttrium content and sintering temperature increase. However, this has the side effect of lowering fracture strength.[7,8]

To increase the translucency values of zirconia, residual pores and impurities that create different refractive indices and lead to optical scattering and translucency reduction on the surface should be reduced.[2,9] Adding alumina to zirconia improves mechanical properties and prevents low-temperature degradation (LTD), but it is the most common cause of impurity.[10,11] Zirconia and alumina have different refractive indices, and therefore, alumina content can reduce inline light transmission when zirconia is added, thereby reducing translucency.[12]

As a result, the yttrium content of the dental zirconia was increased. Although the cubic phase of zirconia added with 8 mol% yttrium is completely stabilized, zirconia with 5% mol yttrium added forms the partially stabilized zirconia containing ~50% cubic phase zirconia.[7] Because zirconia's cubic phase is isotropic in multiple crystallographic directions, light scattering at its boundaries is reduced. Cubic zirconia seems more translucent as a result. Because stabilized cubic zirconia does not transform at room temperature, it does not undergo transformation, hardening, or degradation when exposed to low temperatures.[13,14] In other words, its mechanical characteristics have decreased, but it will not alter over time. Zirconia containing both 0.05% alumina and 5 mol% yttria-stabilized by weight is called polycrystalline (5Y-ZP). Translucent zirconia, however, has mechanical and optical qualities that differ from first- and second-generation zirconias.[2,13]

Monolithic zirconia was found to be the most chosen material for posterior single crowns, whereas lithium disilicate was shown to be the most preferred material for anterior single crowns, according to a 2015 study.[15] This can be related to the mechanical features of zirconia as well as the aesthetic features of lithium disilicate. The introduction of 5Y-ZP promises translucency strength comparable to lithium disilicate zirconias; however, these claims must be verified. In addition, the clinical features of 5Y-ZP with previous generations of zirconia must be evaluated. For example, it should be investigated whether it bonds similarly to methacryloyloxydecyl dihydrogen phosphate (MDP)-containing primers and air abrasion.[5,16] Since there are not enough studies on these issues in the literature, the aim of this study is to examine the new translucent zirconia material. Therefore, the first goal in this study is to conduct research on the claims that the new translucent zirconia is aesthetic in the anterior region and also to compare the clinical properties of 5Y-ZP with previous generations of zirconia. Whether it has similar bonding abilities must also be investigated because of the lack of sufficient literature. For this reason, the second goal of this study is to compare the long-term bond strength of two adhesive resin cements and 5Y-ZP to 3Y-TZP and lithium disilicate. Therefore, the null hypothesis of this study is that the translucency property tested with 5Y-ZP will not differ from that of lithium disilicate ceramic, that it is suitable for anterior aesthetics, and that there will be no difference between other materials compared for the tested bond strength values.

Materials and Methods

Katana UTML (Kuraray Noritake) shade A1 was chosen as the 5Y-ZP material for this study (Kuraray Noritake Dental). Katana HT color HT10 was chosen as the standard 3Y-TZP material. IPS e.max CAD LT shade A1 was chosen as the reference lithium disilicate material (Ivoclar Vivadent AG). IPS e.max CAD HT shade A1 was also used for the translucency parameter (TP). Ceramic was sectioned into 1.1-mm (lithium disilicate) or 1.5-mm (zirconia) thick blocks with a circular sectioning blade and silicon carbide abrasive paper. Then, it was sintered or crystallized according to the manufacturer's recommendations. Then, it was polished (both sides) to a final thickness of 1 mm with 1200-grit. Silicon carbide paper which was used to prepare specimens for testing translucency (n = 10). To duplicate the production process in a dental laboratory, lithium disilicate specimens were wet-sectioned, whereas zirconia specimens were dry-sectioned. With digital calipers, all dimensions were determined to be within 0.1 mm of each other.[2] A spectrophotometer (VITA Easyshade Vident, Brea, Calif.) was used to measure L*a*b* values against a black-and-white background (n = 10). The measuring surface of the spectrophotometer is 3 mm in diameter, and the measurements were made by placing the samples in the middle of this surface. TP values were calculated using the translucency formula.[17,18]

With the help of computer-aided design/computer-aided manufacturing (CAD/CAM) software (SolidWorks, Dassault Systemes, Waltham, USA), the samples in Katana UT and Katana HT and IPS e.max CAD groups are 1 mm in diameter and 3 mm in height; It was designed in a cylindrical shape. The designed samples were obtained by engraving in a milling unit (Camcube M20, CAMcube A.Ş, İzmir, Turkey) with another CAD/CAM software (hyperDENT, FOLLOW-ME! Technology Group, Munich, Germany). Sectioning the ceramic into blocks, sintering or crystallizing according to the manufacturer's recommendations, and polishing with 1200-grit silicon carbide paper were used to create specimens for measuring shear bond strength (n = 10/group). For 20 s, the lithium disilicate specimens were etched with 9.5% hydrofluoric acid (Bisco, Chicago, USA). The zirconia specimens were particle abraded for 10 s at 0.2 MPa with 50-mm alumina. In addition, 10 samples of IPS e.max CAD, Katana UT, and Katana HT groups with Panavia SA adhesive cement system (Kuraray Noritake Dental) according to the manufacturer's instructions. Since the cement contains MDP monomer (increases bonding to zirconia) and Long Carbon-chain Silane Coupling Agent (LCSi) monomer (increases bonding to lithium disilicate ceramics), primer treatment was not applied. After the cement application, light was applied for 3–5 s, and cement residues were removed using a microbrush. Finally, it is cemented by using light polymerized resin cement with a BLUE LED* (800–1400 mW/cm^2) device. For the other 10 samples, using the Panavia V5 adhesive cement system (Kuraray Noritake Dental) according to the manufacturer's instructions; Panavia V5 Tooth Primer (Kuraray Noritake Dental) was applied to the dentin surfaces by agitating for 20 s and dried with light air, Ceramic Primer Plus (Kuraray Noritake Dental) with MDP content was applied to the contact surfaces of the ceramics, then light was applied for 3–5 s by applying cement, and the cement residues were removed by using microbrush. Finally, it is cemented by using light polymerized resin cement with a BLUE LED* (800–1400 mW/cm^2) device.[5]

After the specimens whose cementation was completed were kept in an oven at 37°C with 90% humidity for 24 hours, this situation was defined as 0 thermocycle. For this purpose, 5000 thermal cycles were applied to the samples in a thermal cycle device (Gökçeler Makine, Sivas, Turkey), with a waiting time of 7 s in the transitions between hot and cold chambers, with a 20-s immersion time between 5°C and 55°C.[19]

Bond strength testing was performed using a universal test device (Shimadzu, Model AGS-X5 kN, Shimadzu Corporation, Kyoto, Japan). The specimens were fixed to specially prepared holder assemblies, and the tip of the cutting blade in the universal test device was placed in the device in such a way that it made a 90° angle with the 1-mm thick cutting tip, at the junction of the ceramic specimens and the dentin tissue. A force was applied so that the cutting tip placed on the device was moving at a speed of 0.5 mm/min, coinciding with the interface of the samples. The moment of breakage of the samples was determined as a sudden drop by the computer program connected to the universal testing device (Shimadzu Autograf AG-5 kNG, Kyoto, Japan), and the values at that point were recorded. Obtained data were converted into joint strength data using the following formula.[20]

A total of three ceramic samples and one dentin sample from each group were separated for scanning Auger microscopy (SAM) analysis. The analysis was performed after the surfaces of the samples were coated with Two hundred angstrom (A°) gold by using scanning electron microscope in İzmir Katip Çelebi University MERLAB research laboratory.

Data were analyzed in the statistical package program IBM SPSS Statistics Standard Concurrent User V 26 (IBM Corp., Armonk, New York, USA). Descriptive statistics are given as number of units (n), percentage (%), mean standard deviation. The normal distribution of the data of the bond strength and TP was evaluated with the Shapiro-Wilk test of normality and Q–Q graphs, and the homogeneity of the variances was evaluated with the Levene test. Block effect, cement system effect, and block*cement system interaction effect of bond strengths were evaluated according to two-factor analysis of variance from general linear models. Sidak multiple comparison test was used to determine different groups in the two-factor analysis of variance. One-way analysis of variance was used to compare the TP between groups. Multiple comparisons were evaluated with the Tukey HSD test. Types of rupture and groups were evaluated with Fisher's exact test in tables r × c. If the Fisher exact test result was significant, the differences between the groups were evaluated with the Bonferroni-corrected two-ratio z-test. A value of $P < 0.05$ was considered statistically significant.[21]

Results

It has been reported in the literature that 10–13 MPa values are sufficient for long-term bond strength. Therefore, the IPS e.max CAD*SA group showed insufficient bonding, but all other groups showed sufficient bond strength. The H0 hypothesis, which stated that there will be no difference in bond strength of cubic zirconias with other groups and that they will show sufficient bonding, has been accepted [Table 1].

According to the results of one-way analysis of variance, a statistically significant difference was found between the TP values of the groups. According to Tukey's honestly significant difference (HSD) multiple comparisons, the values of the three groups are statistically different from each other. While IPS e.max CAD group has the highest TP values, the Katana HT group has the lowest values. Therefore, the H0 hypothesis, which claimed that cubic zirconias would show translucency values close to lithium disilicate, was rejected [Table 2].

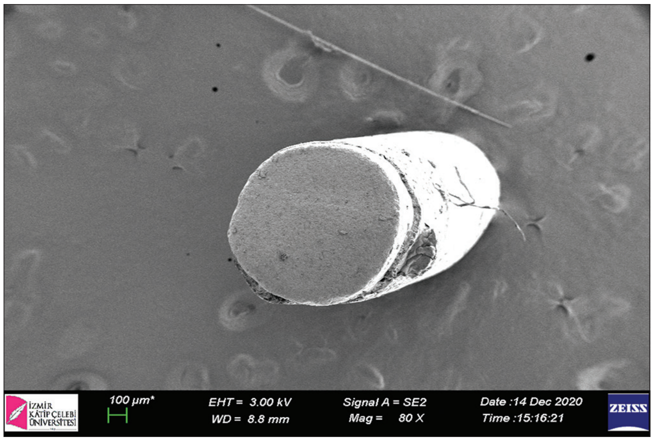

Figure 1: Scanning electron microscope images showing adhesive failure (original magnification 80x)

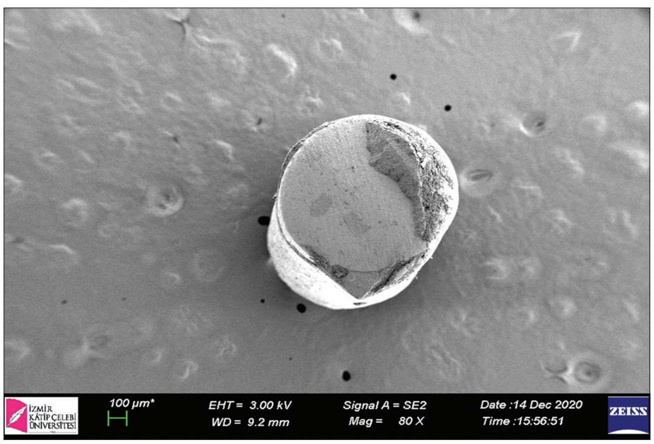

Figure 2: Scanning electron microscope images showing mix failure (original magnification 80x)

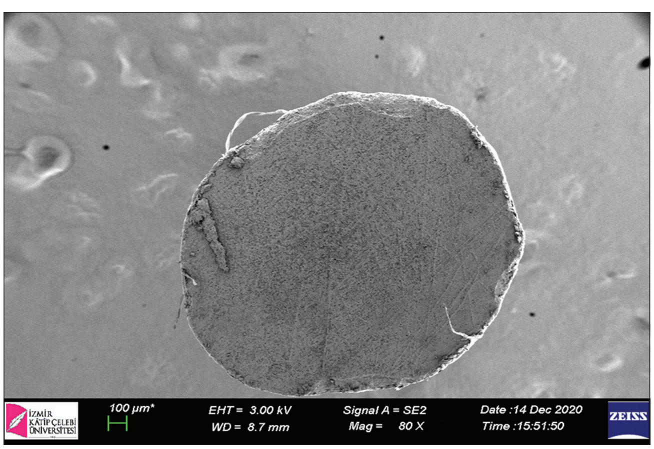

Figure 3: Scanning electron microscope images showing cohesive failure (original magnification 80x)

Deattachment in bonding to ceramic for Panavia SA cement; adhesive failure [Figure 1] was observed two (one Katana UT and one Katana HT) of 30 specimens, mixed failure [Figure 2] was observed eight (four IPS e.max CAD and four Katana UT) of 30 specimens and cohesive failure [Figure 3] was observed 20 (six IPS e.max CAD, five Katana UT, nine Katana HT) of 30 specimens [Table 3].

Table 1: Bond strength value of adhesive systems with different ceramic materials

Block	Adhesive system	$\bar{x}$±*ss*	Effect of block	Effect of adhesive system	Effect of block* adhesive system
E-max	Panavia SA	5,87±1,38[a]	*F*=7,410	*F*=181,627	*F*=17,306
	Panavia V5	28,41±4,91[b]	*P*=0,001	*P*<0,001	*P*<0,001
Katana UT	Panavia SA	9,66±3,82[a]			
	Panavia V5	20,09±3,46[cd]			
Katana HT	Panavia SA	15,29±5,28[d]			
	Panavia V5	24,22±4,01[bc]			

$\bar{x}$=Arithmetic mean, *ss*=Standard deviation. Superscripts *a, b, c*, and *d* indicate the difference between groups. Groups with the same letters are statistically similar

Table 2: Translucency parameter value of different ceramic materials

	Groups			Statistics	
	E-max $\bar{x}$±*ss*	Katana UT $\bar{x}$±*ss*	Katana HT $\bar{x}$±*ss*	*F*	*P*
TP	18,37±1,00[a]	13,47±0,82[b]	11,27±0,47[c]	209,817	<0,001

$\bar{x}$=Arithmetic mean, *ss*=Standard deviation. Superscripts *a, b*, and *c* indicate the difference between groups. Groups with the same letters are statistically similar

Table 3: Failure types

Groups	Failure types					
	Dentin-resin			Ceramic-resin		
	Adhesive	Cohesive	Mix	Adhesive	Cohesive	Mix
E-max*SA	8	-	2	-	6	4
KatanaUT*SA	6	-	4	1	5	4
KatanaHT*SA	4	-	6	1	9	-
E-max*V5	-	-	10	-	5	5
KatanaUT*V5	-	-	10	1	4	5
KatanaHT*V5	-	-	10	1	-	9

Deattachment in bonding to ceramic for Panavia V5 cement, adhesive failure was observed in two (one Katana UT and one Katana HT) of 30 specimens, mixed failure in bonding to ceramic was observed 19 (five IPS e.max CAD, five Katana UT, nine Katana HT) of 30 specimens and cohesive failure in bonding to ceramic was observed nine (five IPS e.max CAD, four Katana UT) of 30 specimens [Table 3].

Deattachment in bonding to dentin for Panavia SA cement; adhesive failure was observed in 18 (eight IPS e.max CAD, six Katana UT, and four Katana HT) of 30 specimens, mixed failure was observed in 12 (two IPS e.max CAD, four Katana UT, and six Katana HT) of 30 specimens and no cohesive failure was observed [Table 3].

Deattachment in bonding to dentin for Panavia V5 cement; mixed failure was observed in 30 (10 IPS e.max CAD, 10 Katana UT, 10 Katana HT) of 30 specimens; no adhesive failure and cohesive failure were observed [Table 3].

Discussion

The first null hypothesis was rejected since the results demonstrate that 5Y-ZP is between 3Y-TZP and lithium disilicate in terms of translucency. The second null hypothesis, that there would be no variation in bond strength across all materials, was not rejected. 5Y-ZP demonstrated long-term bonding capabilities comparable to 3Y-TZP and lithium disilicate (treated according to manufacturer's specifications) after airborne particle abrasion and the application of an MDP-containing primer.

The findings of this study follow the same results as previous research. Because 5Y- ZP has a lower translucency than lithium disilicate (IPS e.max CAD LT), 5Y-ZP has some limitations for highly translucent anterior monolithic restorations. The Translucency Parameter (TP) for 1 mm of human enamel is 18.7, while the for dentin is 16.4.[18] If the L*a*b* values from the current study were converted to the TP in DE, the mean values for Katana HT, Katana UTML, and IPS e.max CAD LT would be 9.86 for Katana HT, 11.28 for Katana UTML, and 13.68 for IPS e.max CAD LT. As indicated by these findings, even lithium disilicate may benefit from the addition of additional translucent porcelain to approximate enamel translucency. The rise in translucency from 5Y-ZP to 3Y-TZP, on the other hand, makes this material better suited for monolithic anterior restorations. In some clinical situations, the material's opacity may help mask discolored substructures or cement.

Furthermore, Kwon *et al*.[5] discovered that 5Y-ZP (cubic zirconia) has lower translucency than lithium disilicate (IPS e.max CAD LT), limiting its usage for monolithic anterior restorations; yet, it will still be limited for translucent restorations.

In another investigation, total light transmittance was reported as 20.18% for Katana HT, 23.37% for Katana UTML, and 27.05%for IPS e.max CAD LT, respectively[2] The medium translucency and strength of 5Y-ZP compared to 3Y-TZP and lithium disilicate raises issues about indications of its clinical usage.

According to Luthy *et al*.,[22] the minimum bond strength required to short- and long-term survival should be ~10–13 MPa. In this study, the long-term bond strength values of cubic zirconia material have been obtained with sufficient results.

After alumina airborne-particle abrasion and the application of an MDP-containing primer, an effective bonding to resin cement was established to 5Y-ZP, similar to previous experiments with 3Y-TZP.[16,23] In the study of De Souza *et al*.,[24] explained the difference between the groups that they used MDP-containing primer compared to the group that they did not use, as the MDP- based primer reduced the contact angle between the resin and ceramic and consequently increased the bonding. In addition, Kim *et al*.[25] stated that contact angles and surface energy parameters have a great effect on the bond between resin and cement. Therefore, in this study, MDP-based primer is an important factor for all block groups.

According to Luthy *et al*.[22] and other investigations, viscosity, wetting capacity, and changes in chemical composition and mechanical features may all have a role in bonding capacity to ceramics. In this study, the fact that Panavia SA cement is more viscous than V5 cement is one of the reasons for its lower bond strength.

Self-adhesive systems tend to have significant amounts of water in their formulation. They may be prone to hydrolysis and chemical degradation over time. Due to the hydrophilicity of self-adhesives, there are studies reporting that even after polymerization, there are semi-permeable membranes that allow water to move through the adhesive layer. Therefore, thermal aging has a negative effect on the bond strength of self-adhesive systems.[26–28]

Muller *et al*.,[29] in their study, in which they compared the water solubility and water absorption of six different resin cements (RelyX Unicem 2 Automix, RelyX Ultimate, Multilink Speed CEM, Multilink Automix, Panavia SA Plus, Panavia V5) according to International Organization for Standardization (ISO) 4049 standards, it was determined that the Panavia V5 (PV5) resin cement was statistically superior to other cements stated that they showed significantly lower ($P < 0.001$, 20.8 ± 0.4 μg mm-3) water absorption. They stated that after the thermal cycle application, the water absorption of both the dual-cure PV5 sample group was statistically significantly ($P < 0.001$) less than the other cement groups. In addition, they stated that PV5 resin cement was less affected by the thermal cycle than other cements in the study due to its low water absorption.[29] This supports the fact that the bond strength values of PV5 resin cement after thermal cycle application are higher than the values of PSA resin cement in this study.

The fact that resin cements do not bond as well as glass matrix-containing ceramics to zirconia substructures is frequently mentioned in the literature, and studies on this subject continue. This supports the results of this study. Although HF acid was applied to IPS e.max CAD blocks and Panavia SA cement contains silane bonding agent, it showed less bonding and insufficient long-term bonding than zirconia ceramics. When self-adhesive resin cements were compared with conventional resin cements in a study by Tian *et al*.,[30] self-adhesive cements were found to be prone to water absorption. For this reason, it was stated that the combination of etching and silanization with hydrofluoric acid is a recommended and necessary method for bonding glass matrix ceramics in self-adhesive systems. This supports the results of this study with the self-adhesive Panavia SA cement. It is thought that silane should be applied extra to the IPS e.max CAD group containing glass matrix.

The type of failure gives important information in bond strength tests. In many studies in the literature, it has been reported that adhesive detachment [Figure 1] is more common on surfaces with low bond values, and mixed [Figure 2] and cohesive-type detachment [Figure 3] types are predominant on surfaces with high bond values.[31,32] In this study, more cohesive and mixed detachment were observed in all groups that were considered to have sufficient long-term bond strength values. The information that adhesive bond failures are associated with low bonding also explains the IPS e.max CAD SA group, which showed the most adhesive failure and the lowest bond strength in this study. According to the detachment type results of this study, in the ceramic-resin bond, mostly cohesive or mixed ruptures were observed, but according to the dentin bonding results, PV5 cement did not show adhesive failure, while PSA cement showed adhesive failure for each block group. This shows that PSA cement is actually bonded to ceramics, but is insufficient before bonding to dentine.

Conclusion

1. The long-term bond strength of cubic zirconias was similar to 3Y-TZP zirconias and lithium disilicate ceramics and showed sufficient bond strength.
2. It is thought that cubic zirconias, especially preferred in the anterior regions, can be an alternative to glass ceramics if their optical properties are improved.
3. The lowest bond strength results were obtained for each group cemented with Panavia SA, with surface treatments applied but without primer application.
4. Samples of each group cemented with Panavia V5 showed successful bond strength values.

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Conflicts of interest

There are no conflicts of interest.

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