

A Comparative Evaluation of Temperature Changes in the Pulpal Chamber during Direct Fabrication of Provisional Restorations: An In Vitro Study

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Abstract To compare the temperature changes in the pulpal chamber during fabrication of provisional restorations by direct method. A total of 108 three-unit FPD provisional restorations were fabricated on a study model and divided into three main groups according to the material used for the fabrication of matrix. Group A—Alginate impression index group, Group B—Polyvinylsiloxane putty impression index group, Group C—Vacuum formed template group. Each group comprising of 36 specimens, was subdivided into three subgroups based on the provisional restorative material used: polymethylmethacrylate (subgroup 1), polyethylmethacrylate (subgroup 2), bis-acryl composite resin (subgroup 3). Intrapulpal temperature changes were observed with the help of a thermocouple probe (connected to a digital microprocessor thermometer) inserted into the pulp chamber of an extracted mandibular second molar mounted on a study model, during the fabrication of provisional restorations by direct method. The subgroups mean temperature rise observed in Group A—A1, A2, A3 was 2.6250 ± 0.2491 , 1.0500 ± 0.1382 , 0.4083 ± 0.1165 , respectively. The subgroups mean temperature rise observed in Group B—B1, B2, B3 was 4.6250 ± 0.2454 , 3.3750 ± 0.3415 , 2.5917 ± 0.2678 , respectively. The subgroups mean temperature rise observed in Group C—C1, C2, C3 was 4.7694 ± 1.8361 , 3.0611 ± 1.5767 , 2.3806 ± 1.5713 , respectively. The observations were statistically significant. The intrapulpal temperature rise during fabrication of a provisional restoration depended both on the type of provisional restorative material and the type of matrix used. The clinician should

choose carefully the resin and the matrix material while fabricating provisional restorations with direct method.

Keywords Provisional restoration · Matrix · Temperature rise · Thermocouple probe

Introduction

Provisional restorations are an integral part of fixed prosthodontic treatment. One of the important requirements of these materials is that they should be non irritating to pulp and to other tissues and should have low exothermicity.

Amongst the two principal methods of fabrication; *direct* (in the patient's mouth) and *indirect* (on the stone cast), the direct method is associated with two major problems: exposure of the tooth structure to the heat produced by polymerization of resins and to acrylic resin monomer. The purpose of this in vitro study was to compare the temperature changes in the pulp chamber during direct fabrication of provisional restorations.

Materials and Methods

Fabrication of Study Model

A model was constructed representing a dentulous mandibular arch with missing right first molar.

A complete arch typodont model was duplicated in agar. Extracted natural teeth (second premolar and second molar) of average size and form were selected for use in this model. The teeth were placed in their respective positions in the duplicated agar mould. The mould was then completely filled with molten modeling wax

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(Y-Dents, Delhi). After solidifying, wax model was retrieved from the mould, the natural teeth were aligned slightly and the model was smoothed. An alginate impression was made of the wax model and poured in type IV dental stone to be later used in the fabrication of matrices. The pontic space was then carved and contoured by removing the wax tooth in 1st molar region and the model was refined.

The model was invested and after dewaxing the two natural teeth were retrieved. The root of 2nd molar was sectioned approximately 3 mm below the CEJ. The pulp chamber was cleaned of organic debris. A thermocouple probe (Cr/Al type, 1 mm diameter) was positioned inside the pulp chamber (attached to digital microprocessor thermometer on the other end) and amalgam was condensed around the probe, filling the pulp chamber. The tip of the probe is the only part sensory to the temperature changes. Silver amalgam condensed around the probe tip acts as heat conduction medium from dentin to thermocouple probe.

The two teeth [2nd premolar and 2nd molar (with the probe)] were placed in their respective positions in the

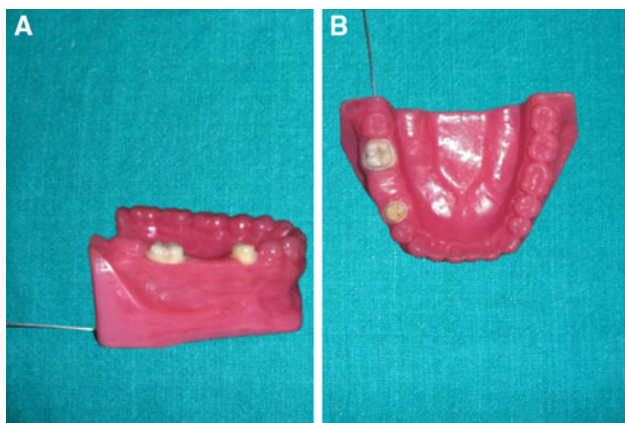


Fig. 1 a Lateral view and b Occlusal view of study model

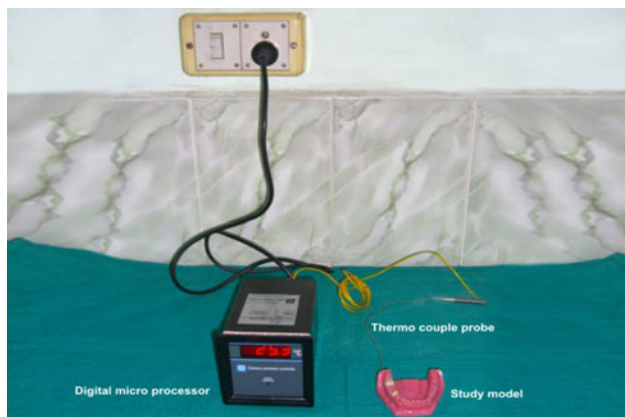


Fig. 2 Complete set up used in the study

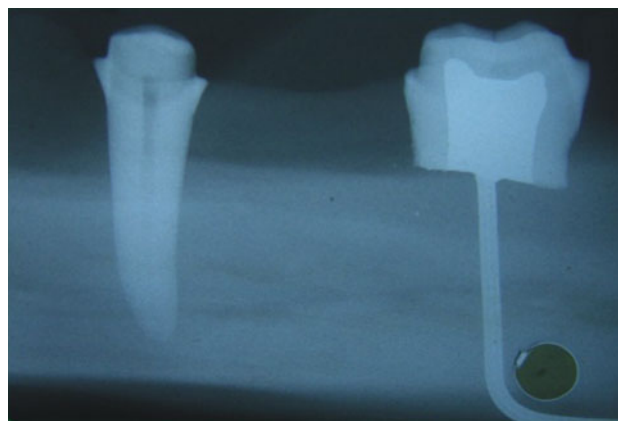


Fig. 3 IOPA showing thermocouple probe within pulp chamber

plaster mould obtained after dewaxing. After applying cold mould seal (DPI, Mumbai, India), the mould was then processed with autopolymerising acrylic resin (DPI—RR cold cure, DPI, Mumbai, India). The acrylic resin model was then recovered, trimmed and polished. The two natural teeth (2nd premolar and 2nd molar) were then prepared for complete coverage porcelain fused to metal retainers (Figs. 1, 2, 3). The model was now ready for fabrication of specimens.

Study Groups

Three different self cure provisional restorative resins were tested for variations caused by them in the temperature of pulp chamber during fabrication of provisional fixed partial denture by direct technique. The resins used were: Poly-methyl methacrylate (PMMA) resin (DPI, Mumbai, India), Polyethyl methacrylate (PEMA) resin (Splintline, Lang Dental Manufacturing Co, IL, USA), bis-acrylic composite resin (Protemp-II 3M-ESPE, Germany) (Fig. 4). Also, the effect of the three different matrices used for their

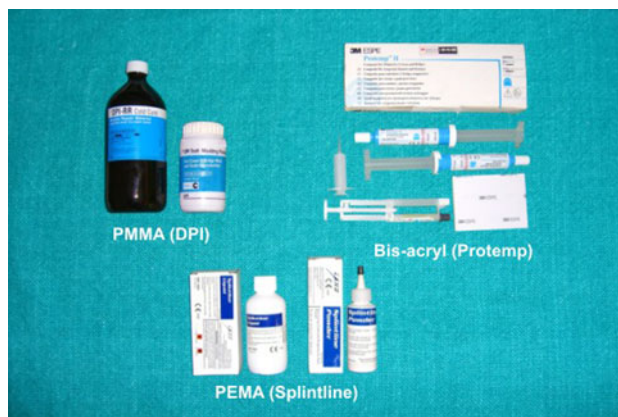


Fig. 4 Temporary crown and bridge resins



Fig. 5 Matrix materials

fabrication, on this temperature change was evaluated. The materials used for matrix fabrication were: Irreversible hydrocolloid (alginate) (Plastalgin, Septodont, Cedex, France), Polyvinyl siloxane putty (Aquasil Soft putty, Dentsply, Germany), 1 mm thick thermoplastic Sheet (Duran, Libral traders, New Delhi) (Fig. 5).

The study was divided into three groups according to the matrix used for the fabrication of provisionals:

Group A: Irreversible hydrocolloid (alginate) impression index group.

Group B: Polyvinyl siloxane putty impression index group.

Group C: Vacuum formed template group.

Each group was further divided into three subgroups as follows:

Subgroup 1: Provisional restorations made with PMMA resin (DPI).

Subgroup 2: Provisional restorations made with PEMA resin (Splintline).

Subgroup 3: Provisional restorations made with bis acryl composite resin (Protemp II).

So, the study groups could be summarised as follows:

Group A: Subgroups A₁, A₂, A₃.

Group B: Subgroups B₁, B₂, B₃.

Group C: Subgroups C₁, C₂, C₃.

Fabrication of Matrices

The matrices were fabricated as follows:

Irreversible hydrocolloid (alginate) matrix: The stone cast was immersed in a plaster bowl of water for 5 min. Wetting the cast in this manner will prevent the alginate from adhering to it. Alginate was mixed according to manufacturers instructions and loaded in posterior sectional

tray. The sectional tray with alginate was positioned over the stone cast, to make an impression. A new impression was made for each trial.

Polyvinyl siloxane putty matrix: Before making the matrix, the impression tray was painted with tray adhesive and allowed to air dry for 5 min. Equal and constant proportion of base and catalyst of polyvinyl siloxane putty impression material were mixed by kneading in the hands and placed in sectional tray to make an impression of the stone cast. Excess impression material from the borders was trimmed to facilitate accurate re-placement on the study model. Total three impressions were made to fabricate provisional restorations with the three resins in the study.

Vacuum formed template matrix: Thermoplastic sheet was adapted over the stone cast using thermal vacuum forming machine. The vacuum template was trimmed 5 mm below the CEJ of the teeth and was also cut such that it extended one tooth on either side of the prepared teeth to serve as stops. A total of three such templates were fabricated.

Fabrication of specimens

The microprocessor thermometer was switched on and the reading was noted. Petroleum jelly was applied to the teeth and surrounding acrylic resin model. A small portion of the aluminium foil was adapted over the pontic space and around the gingival areas of the abutment teeth to prevent provisional resin from adhering to the model.

For all techniques the provisional resin materials were measured and mixed according to manufacturer's recommendations. The resins were placed into the matrix, which was then seated on the prepared abutment teeth. The temperature was recorded at 30 s intervals using the microprocessor thermometer, which read in 0.1°C increments. Temperature monitoring was ceased after it was evident that the peak temperature had been reached.

Temperature change for each specimen was calculated as follows:

$$\text{Temperature change} = \text{Peak temperature noted during the fabrication} - \text{Temperature recorded at the start of provisionalization}$$

All specimens displayed a rise in intrapulpal temperature.

Since, the materials and models were at room temperature (22–23°C) when the test began, any increase in temperature in the pulp chamber was attributed to the heat of resin polymerization transmitted to the pulp chamber containing silver amalgam and the thermocouple probe. Intrapulpal temperature variations were recorded, tabulated and statistically analyzed.

Results

The mean temperature rise of Groups A, B and C were calculated and are presented in Table 1 and Fig. 6.

Student's *t* test was applied to determine the significance of statistical difference between the means within the groups (intragroup comparison) and across the groups (intergroup comparison). These comparisons have been presented in Tables 2 and 3.

The results of Student's *t*-test for intragroup comparison (Table 2) showed statistically significant differences between the means of temperature rises of resins within each main group when considering means in pairs and analyzing these pairs one by one i.e. on pair wise comparison, a statistically significant difference was detected while comparing means of temperature rises of resins with a particular matrix.

The Student's *t*-test when applied for intergroup comparison (Table 3) also showed statistically significant differences between the means of temperature rises of the main groups of a particular subgroup when considering means in pairs and analyzing these pairs one by one i.e. on pair wise comparison, a statistically significant difference was detected while comparing means of temperature rises of a particular resin in the presence of different matrices.

Discussion

Several studies have described the heat producing capability of commonly used resin materials for the fabrication of provisional restorations [1–5].

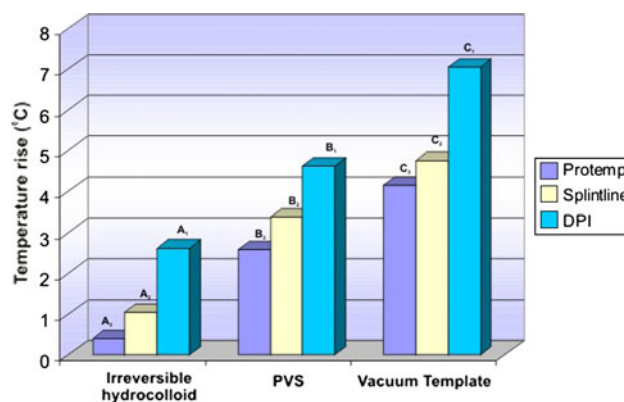


Fig. 6 Bar graph showing comparison of means of temperature rise of resins within each main group

The heat transferred to the tooth is also influenced by the choice of matrix used to hold the provisional material, as the matrix acts as a heat sink to some extent. The use of polyvinyl siloxane materials as the matrix has been shown to significantly reduce peak polymerization temperature as compared with the use of vacuum formed polypropylene matrix material [1, 4]. Irreversible hydrocolloid (alginate) has been shown to produce least temperature rise in pulp when used as a matrix during direct fabrication of provisionals [6, 7].

This study showed that with each matrix or in each group, the temperature rise was greatest with PMMA (DPI) followed by PEMA (Splintline) and bis-acryl (Prottemp) in all the groups (i.e. matrices) (Table 1; Fig. 6). The results were found to be statistically significant ($P < 0.001$) (Table 2).

Table 1 Mean values, range and standard deviation for the temperature rise values of the specimens in the study

Main group	Subgroup	Mean (°C)	Range (°C)		Standard deviation	N
			Min.	Max.		
Group A (Alginate matrix)	DPI (A ₁)	2.6250	2.2	3.0	0.2491	12
	Splintline (A ₂)	1.0500	0.8	1.2	0.1382	12
	Prottemp (A ₃)	0.4083	0.3	0.6	0.1165	12
	Total	1.3611	0.3	3.0	0.9601	36
Group B (PVS matrix)	DPI (B ₁)	4.6250	4.3	4.9	0.2454	12
	Splintline (B ₂)	3.3750	2.9	3.8	0.3415	12
	Prottemp (B ₃)	2.5917	2.2	2.9	0.2678	12
	Total	3.5306	2.2	4.9	0.8940	36
Group C (Vacuum template matrix)	DPI (C ₁)	7.0583	6.3	7.6	0.4100	12
	Splintline (C ₂)	4.7583	4.4	5.3	0.3343	12
	Prottemp (C ₃)	4.1417	3.6	4.5	0.3088	12
	Total	5.3194	3.6	7.6	1.3184	36
Total	DPI	4.7694	2.2	7.6	1.8361	36
	Splintline	3.0611	0.8	5.3	1.5767	36
	Prottemp	2.3806	0.3	4.5	1.5713	36
	Total	3.4037	0.3	7.6	1.9431	108

N number of specimens

Table 2 Results of Student's *t*-test for Groups A, B and C (intragroup comparison)

Groups	Subgroups	Mean \pm SD	Comparison	<i>t</i> -value	df	<i>P</i> -value
A (Alginate matrix)	DPI (A ₁)	2.6250 \pm 0.2491	A ₁ vs. A ₂	19.154	22	<0.001
	Splintline (A ₂)	1.0500 \pm 0.1382	A ₁ vs. A ₃	27.926	22	<0.001
	Protemp (A ₃)	0.4083 \pm 0.1165	A ₂ vs. A ₃	12.301	22	<0.001
B (PVS Putty matrix)	DPI (B ₁)	4.6250 \pm 0.2454	B ₁ vs. B ₂	10.298	22	<0.001
	Splintline (B ₂)	3.3750 \pm 0.3415	B ₁ vs. B ₃	19.389	22	<0.001
	Protemp (B ₃)	2.5917 \pm 0.2678	B ₂ vs. B ₃	6.253	22	<0.001
C (Vacuum Template matrix)	DPI (C ₁)	7.0583 \pm 0.4100	C ₁ vs. C ₂	15.061	22	<0.001
	Splintline (C ₂)	4.7583 \pm 0.3343	C ₁ vs. C ₃	19.683	22	<0.001
	Protemp (C ₃)	4.1417 \pm 0.3088	C ₂ vs. C ₃	4.694	22	<0.001

$P > 0.05$ —not significant, $P \leq 0.05$ —significant, $P < 0.01$ —highly significant, $P < 0.001$ —very highly significant
df degree of freedom

Table 3 Results of Student's *t*-test for inter group comparison

Subgroups	Groups	Mean \pm SD	Comparison	<i>t</i> -value	df	<i>P</i> -value
DPI	Alginate index (A)	2.6250 \pm 0.2491	A ₁ vs. B ₁	−19.813	22	<0.001
	PVS putty index (B)	4.6250 \pm 0.2454	A ₁ vs. C ₁	−32.012	22	<0.001
	Vacuum Template (C)	7.0583 \pm 0.4100	B ₁ vs. C ₁	−17.640	22	<0.001
Splintline	Alginate index (A)	1.0500 \pm 0.1382	A ₂ vs. B ₂	−21.865	22	<0.001
	PVS putty index (B)	3.3750 \pm 0.3415	A ₂ vs. C ₂	−35.515	22	<0.001
	Vacuum Template (C)	4.7583 \pm 0.3343	B ₂ vs. C ₂	−10.028	22	<0.001
Protemp	Alginate index (A)	0.4083 \pm 0.1165	A ₃ vs. B ₃	−25.896	22	<0.001
	PVS putty index (B)	2.5917 \pm 0.2678	A ₃ vs. C ₃	−39.183	22	<0.001
	Vacuum Template (C)	4.1417 \pm 0.3088	B ₃ vs. C ₃	−13.134	22	<0.001

$P > 0.05$ —not significant, $P \leq 0.05$ —significant, $P < 0.01$ —highly significant, $P < 0.001$ —very highly significant
df degree of freedom

The possible reason for this heat release could be that the chemical reaction of the polymer-based provisional materials is an addition polymerization. As the polymerization proceeds, carbon–carbon double bonds are converted to new carbon–carbon single bonds. This process emits heat.

All the three resins exhibited exothermic behaviour in the study. PMMA showed the highest mean temperature rise followed by PEMA and bis-acryl composite resin, in all the three groups. This can be explained by the fact that the chemical composition of acrylic resin affects the peak temperature at the time of polymerization. PMMA usually contains hydroquinone as the inhibitor and *N,N*-dimethyl-*p*-toulidine (DMPT) as an accelerator. Peak temperature is affected not only by the increased concentration of the accelerator, but also by the type of accelerator. Peak temperature on polymerization gets reduced by substitution of higher molecular weight methacrylates for methyl methacrylate [e.g. substitution of methyl methacrylate by ethyl methacrylate and methacrylate esters (bis-acryl composite)].

When the effect of presence of matrices on intrapulpal temperature rise was evaluated (i.e. the temperature rise values of each resin with three different matrices), the intrapulpal temperature rise was highest with vacuum formed template followed by PVS putty and alginate. The results were also found to be statistically significant ($P < 0.001$) (Table 3). So, alginate acted as the best heat sink. The water present in the irreversible hydrocolloid would likely have a greater cooling effect which explains the lower temperature rise value of this material.

The mean intrapulpal temperature rise in this study ranged from 0.40°C \pm 0.11 (subgroup A₃) to 7.05°C \pm 0.41 (subgroup C₁). According to the histological studies of Zach and Cohen [8], temperature rises in the pulp chamber greater than 5.6°C are considered unacceptable because of a potential for loss of pulpal vitality. Considering this criterion, if DPI resin is to be used for the fabrication of provisional restorations, vacuum formed template as a matrix should be avoided, because this matrix acts as an insulator rather than acting as a heat sink or a good conductor. It has been observed in the study that the mean

intrapulpal temperature rise caused by bis-acryl resin (Protemp), when used in combination with any of the matrices, is the lowest as compared to the other two (DPI and Splintline) i.e. subgroup 3 has the lowest value amongst all the three main groups (Table 1). So, if vacuum formed template matrix has to be used, a resin which produces low exotherm behaviour like bis-acrylic (Protemp) should be selected.

It was found that there was a greater temperature variation with the change of matrix than with the change of resin material. So, considering the thermal insult to the pulp during direct fabrication of provisional restorations, a change in the matrix material used would have a greater effect in reducing temperature increase than would a change in material.

The temperature rise may be reduced by employing various cooling techniques like *removal*: removing the provisional restoration after the initial polymerization of resin; *using air/water spray*: leaving the resin on the abutment teeth throughout the polymerization and spraying air/water once the initial reaction has occurred; *on/off*: removing the provisional restoration after initial polymerization, flushing the tooth with air/water and then replacing the restoration [6].

Certain things should be considered while interpreting the data from this in vitro study. In clinical conditions, the elevations in temperature are also reduced by presence of the periodontal ligament [7, 9] and other organic structures, such as protoplasmic extensions of cells in dentinal tubules [4]. Pulpal and osseous circulation are also effective in heat dissipation [7, 9].

Other factors to be considered are bulk of the acrylic resin, monomer/polymer ratios, type of resin used in fabricating provisionals. Moulding and Teplitsky [7] found a statistically significant difference in temperature rise in pulp between the single unit and fixed partial dentures. This difference was the result of the increased volume of resin in the adjacent pontic. Vallitu [5] stated that a sphere of acrylic resin will become much hotter than a flat sheet of equal mass.

Because the amount of heat generated is proportional to the volume of material used, for multiple interim crowns or complex fixed partial dentures with multiple pontics, the indirect technique is most often indicated for such cases. The direct technique is well suited for single crowns and short span (up to three units) interim fixed partial dentures [10]. Also, provisional restorations for endodontically treated teeth can be fabricated with direct method.

Moreover, it has also been demonstrated that the intrapulpal temperature rise is always smaller during relining procedures, due to the fact that a smaller volume of resin material used for relining [7, 11]. So, it would be beneficial to fabricate the provisional restorations on a stone

cast and then perform the relining procedures on the prepared teeth.

Direct technique exposes the freshly prepared tooth surface to free monomer during polymerization. To reduce this exposure, use of a dental varnish or petroleum jelly is recommended prior to temporary fabrication [3]. The irritation produced by acrylic resin monomer can also be avoided by using a non monomer containing material such as visible light activated resin [2].

Hence, efforts should be made to minimize potential iatrogenic insult to teeth during fabrication of provisional restorations. Indirect fabrication may be more time consuming but it avoids the exposure of oral and pulpal tissue to monomer and heat generated by the exothermic polymerization reaction of resins. When an indirect technique cannot be used or is impractical, a direct technique that minimizes thermal trauma should be used. It is recommended to use low exotherm provisional restorative material, matrices that have good thermal conductivity and have the capacity to act as a good heat sink.

Conclusion

The following conclusions were drawn from the study:

1. The type of resin used during direct fabrication of provisional restorations affects the intrapulpal temperature rise. Polymethyl methacrylate (DPI) showed the highest temperature rise value followed by polyethyl methacrylate (Splintline) and bis-acrylate composite (Protemp).
2. Intrapulpal temperature rise also depends on type of matrix used during direct fabrication of provisional restorations. The maximum temperature rise was found with vacuum formed template followed by poly vinyl siloxane putty impression index and irreversible hydrocolloid (alginate) impression index.
3. Polymethylmethacrylate (DPI) used with vacuum template as matrix in the study caused temperature elevation above 5.5°C i.e. 7.05°C (temperature above which 15% of pulpal necrosis has been found in a previous study). So, this combination of resin and matrix should be avoided when using direct technique to protect pulp from iatrogenic thermal damage.
4. The resin material recommended for clinical use when direct technique is employed for fabrication of provisional restorations, among the materials tested in the study is bis-acryl composite resin (Protemp) as it caused minimal temperature rise in the pulpal chamber. Irreversible hydrocolloid (alginate) impression index is the recommended matrix material among all the matrices used in the study as it acts as the best heat sink.

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Conflict of interest None declared.

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