

Original Article

The changes of chemical exposure and control measures in general dental offices in Isfahan city, Iran, in 2001–2023

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ABSTRACT

Background: Exposure to chemical substances is one of the occupational hazards among dentists. Therefore, this study aimed to investigate the changes in chemical exposure and control measures in general dental offices in Isfahan city, Iran, from 2001 to 2023.

Materials and Methods: This study was performed with a repeated cross-sectional design. 184 offices were surveyed in 2001 and 250 offices in 2003. Data were collected by a researcher-made checklist. This tool has four parts, including questions related to demographic characteristics, questions related to the time period of exposure, questions related to exposure type and its consequences, and questions related to control measures.

Results: The results showed that although the use of some chemicals has increased or remained unchanged, the use of most chemicals, such as resin-based dental restorative materials, acid etch materials, latex, dental plaster, common disinfectants, and hand hygiene products, has decreased in 2023 compared to 2001 ($P < 0.028$). Moreover, the results indicated that professional control measures, including education, personal protective equipment, engineering control, and several measures, have significantly improved in 2023 compared to those in 2001 ($P < 0.001$).

Conclusion: These findings highlight the importance of improving workplace conditions, implementing control measures, and applying less hazardous materials in dental offices.

Key Words: Chemical exposure, control measures, dental office, dentistry

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INTRODUCTION

Dentistry, as a distinct field within healthcare, focuses on the prevention, diagnosis, and treatment of diseases affecting the oral cavity. It plays a crucial role in overall systemic well-being.^[1] For this purpose, dental professionals perform a wide range of procedures that expose them to various occupational hazards.^[2,3] Exposure to chemical

substances is an important group of occupational hazards among dentists. The exposure to these substances can lead to adverse outcomes, such as contact dermatitis, allergic reactions, pneumoconiosis, reproductive complications, and other toxic effects.^[4]

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Previous studies have tried to identify and evaluate the exposure to chemical substances among dentists. Picard *et al.* conducted a review on occupational exposures to chemicals among dentists. They found that most health assessments focused on mercury, followed by nitrous oxide (N₂O), methacrylate compounds, and silica.^[5] Anjum *et al.* also, in a review, investigated the occupational hazards among dentists. The identified chemical substances included caustics (hydrogen peroxide, and formaldehyde), organic (resins, solvents, and gases), inorganic (mercury toxicity), and latex glove allergy (contact dermatitis).^[6] Naryal *et al.*, in a comprehensive review, examined chemical occupational hazards in dentistry. They concluded that the dentists are exposed to mercury, powdered natural rubber latex (NRL), disinfectants, methyl methacrylate, metal alloys, silica, and N₂O.^[7] Nagpal *et al.* evaluated the mercury exposure and health of dental personnel. They observed that dental professionals may be associated with low-level, long-term exposure to occupational mercury.^[8] However, given the wide variety of materials used in dentistry, a comprehensive assessment is required. On the other hand, because of changes in procedures as well as the implementation of control measures, chemical exposures may alter over time. Gustavsson *et al.* investigated time trends of occupational exposure to chemicals in Sweden. They found that exposure to some chemical agents has changed over time, suggesting alterations in well-controlled working conditions.^[9] Kauppinen *et al.* also examined the trends of occupational exposure to chemical agents in Finland between 1950 and 2020. They observed that there is a reduction in inhalation exposure to most chemicals since 1970.^[10] Given that these temporal changes have not been investigated among dentists, this study aimed to evaluate changes in chemical exposure levels and control measures in general dental offices in Isfahan, Iran, from 2001 to 2023.

MATERIALS AND METHODS

A repeated cross-sectional study was performed in 2001 and 2023 using a researcher-made checklist.

Participation

A total of 184 offices were surveyed in 2001 and 250 offices in 2023. To select this number of samples, a list of all general dental offices in Isfahan was prepared. Based on the statistics represented in 2001

and 2023, there were 350 and 708 active dental offices in Isfahan city, respectively. Using equation 1, the sample size was computed.

$$n = \frac{NZ^2P(1-P)}{(N-1)d^2 + Z^2P(1-P)} \quad (1)$$

Where $Z = 1.96$, $P = 0.5$, $d = 0.05$, $N_1 = 350$, and $N_2 = 708$.

The desired samples were selected by simple random sampling. Then, the selected samples were evaluated in terms of compliance with the inclusion criteria and noncompliance with the exclusion criteria. Inclusion criteria included the presence of a dentist in the office, office location within Isfahan, and the willingness of the dentists to cooperate in the research. The exclusion criteria also were inaccuracy in completing the checklist. This study was approved as a research project by the ethics committee of Isfahan University of Medical Sciences (IR.MUI.RESEARCH.REC.1401.305). All methods were performed in accordance with relevant guidelines and regulations. All subjects gave their written informed consent to participate.

Data collection

First, a list of dental offices in Isfahan province was obtained from the relevant authorities. Then, several offices were randomly selected, and their situations were examined in terms of the criteria. After that, the managers of the selected offices were invited to participate in the study, and the objectives and stages of the study were explained to them. In the next step, the research team visited the offices and asked dentists to complete a researcher-made checklist during their break. During the completion of the checklist, the research team was present at the research site to answer any questions.

Tool

A checklist with four sections was used to collect data. These sections included questions related to demographic characteristics, questions related to the time period of exposure, questions related to exposure type and its consequences, and questions related to control measures. To ensure accuracy and consistency, the checklist was developed based on relevant literature and guidelines and was applied uniformly across all study periods. Demographic questions included age, work experience, gender, and building type. Questions related to the time period of exposure were career length, work duration per day (hours), and work

frequency per week. Questions related to exposure type and its consequences were designed in three groups, including chemicals used in prosthetics, chemicals used in the endo and restorative operations, and chemicals used in infection control. Chemicals used in prosthetics include dental cements' liquid, dental plaster, Optosil putty, xantopren, special tray self-cure acrylic material, self-cure acryl, chloroform solvent, cold-cure acrylic for temporary crown, plasticized acrylic resin soft liner, Speedex impression set, and alginate. Chemicals used in the endo and restorative operation are eugenol, formocresol, formalin, alkaline dental X-ray developer, acidic dental X-ray fixer, acid etch material, resin-based dental restorative material, mercury amalgam powder, and varnish solvent (ether). Chemicals used in infection control include latex, Micro-10 disinfectant, Sidex disinfectant, Savlon, povidone-iodine, bathroom soap, and sodium hypochlorite. To evaluate exposure to these chemical substances and their consequences, the participants answered a question for each substance via five items (1: Without use, 2: With use and without effects, 3: With use and with skin effects, 4: With use and with respiratory effects, and 5: With use and with skin and respiratory effects). Questions related to control measures were the status of total control measures, use of gloves, use of masks, and the status of ventilation. The researchers supervised all completions.

Statistical analysis

SPSS version 26, developed by SPSS Inc., based in Chicago, Illinois, USA, software was used to

analyze the data. Qualitative variables were described using frequency and relative frequency. The Mann–Whitney *U*-test was also used to examine the changes in variables between 2001 and 2023. The accepted significance level was <0.05 .

RESULTS

Table 1 represents the statistical distribution of demographic characteristics among dentists in 2001 ($n = 184$) and 2023 ($n = 250$). There was a difference in sample size between 2001 and 2023. It is due to the increase in the number of dental offices in 2023 compared to 2001. However, to eliminate the effect of this difference, the relative frequency for the parameters in each year was reported. Based on the results, most of the participants in 2001 had work experience of 5–10 years (40.8%), gender of male (75%), and worked in a dental office in a building with multiple floors (94.6%). Most of the participants in 2023 also had an age range higher than 50 years (37.6%), work experience more than 20 years (42.8%), and gender of male (70.8%), and worked in a dental office in a building with multiple floors (91.2%). Among demographic variables, there was a significant difference in the work experience of participants between 2001 and 2023 ($P < 0.001$).

Table 2 reports the statistical distribution of exposure time characteristics among dentists in 2001 ($n = 184$) and 2023 ($n = 250$). The results showed that

Table 1: Statistical distribution of demographic characteristics among dentists in 2001 ($n=184$) and 2023 ($n=250$)

Variable	2001		2023		P
	Frequency (n)	Relative, frequency (%)	Frequency (n)	Relative, frequency (%)	
Age (years)					
<30	-	-	37	14.8	-
31–40	-	-	60	24.0	
41–50	-	-	59	23.6	
More than 50	-	-	94	37.6	
Work experience (years)					
<5	21	11.4	51	20.4	<0.001
5–10	75	40.8	24	9.6	
11–15	41	22.3	35	14.0	
16–20	26	14.1	33	13.2	
More than 20	21	11.4	107	42.8	
Gender					
Male	138	75.0	177	70.8	0.319
Female	46	25.0	73	29.2	
Building type					
One floor	10	5.4	22	8.8	0.191
Multiple floor	174	94.6	228	91.2	

most participants in 2001 had career lengths of 5–10 years (40.8%), work duration per day of more than 6 h (43.5%), and work frequency per week of 4–6 days (83.2%). Most participants in 2023 had career lengths of more than 20 years (42.8%), work duration per day of more than 6 h (57.6%), and work frequency per week of 4–6 days (70.4%). As a result, the career length and work duration per day have significantly increased among participants in 2023 compared to those in 2001 ($P < 0.001$). While work frequency per week has not significantly changed among participants in 2023 compared to those in 2001 ($P = 0.060$).

Tables 3-5 represent the statistical distribution related to type and consequences of exposure to chemicals used in prosthetics, endo, and restorative operations and infection control among dentists in 2001 ($n = 184$) and 2023 ($n = 250$). The results indicated that 22 chemical substances were used in most dental offices in 2001, and 14 chemical substances were applied in most dental offices in 2023.

Among chemicals used in prosthetics, the use of dental cements' liquid, plasticized acrylic resin soft liner, Speedex impression set, and alginate has significantly increased in 2023 compared to those in

Table 2: Statistical distribution of exposure time characteristics among dentists in 2001 ($n=184$) and 2023 ($n=250$)

Variable	2001		2023		P
	Frequency (n)	Relative, frequency (%)	Frequency (n)	Relative, frequency (%)	
Career length (years)					
<5	21	11.4	51	20.4	<0.001
5–10	75	40.8	24	9.6	
11–15	41	22.3	35	14.0	
16–20	26	14.1	33	13.2	
More than 20	21	11.4	107	42.8	
Work hours per day (h)					
<2	17	9.2	4	1.6	<0.001
2–4	45	24.5	43	17.2	
4–6	42	22.8	59	23.6	
More than 6	80	43.5	144	57.6	
Work shift per week					
<2	17	9.2	5	2.0	0.060
2–4	14	7.6	66	26.4	
4–6	153	83.2	176	70.4	
More than 6	0	0.0	3	1.2	

Table 3: Statistical distribution (%) of exposure type and consequence of chemicals used in prosthetics among dentists in 2001 ($n=184$) and 2023 ($n=250$)

Variable	Without use		With use and without effects		With use and with skin effects		With use and with respiratory effects		With use and with skin and respiratory effects		P
	2001	2023	2001	2023	2001	2023	2001	2023	2001	2023	
	Liquid of dental cements	33.7	10.2	61.9	84.5	2.8		0.6		1.1	
Dental plaster	39.8	52.0	48.1	41.6	6.6	6.4	3.9		1.7		0.004
Optosil putty	22.7		68.5		7.2		1.1		0.6		-
Xantopren	25.4		65.7		7.2				1.7		-
Special tray self-cure acrylic material	63.0	71.6	19.9	28.0	3.9	0.4	6.6		6.6		0.004
Self-cure acryl	47.5	76.8	26.0	17.2	6.6	0.4	10.5	5.6	9.4		<0.001
Chloroform solvent	30.9	6.8	39.8	91.2	4.4		20.4	2.0	4.4		0.699
Cold-cure acrylic for temporary crown	17.1	26.4	74.0	72.8			5.5	0.8	3.3		<0.001
Plasticized acrylic resin soft liner	69.6	49.2	27.1	46.0	1.1		1.7	2.8	0.6	2.0	<0.001
Speedex Impression set				100.0							-
Alginate				100.0							-

Table 4: Statistical distribution (%) of exposure type and consequence of chemicals used in the endo and restorative operations among dentists in 2001 (n=184) and 2023 (n=250)

Variable	Without use		With use and without effects		With use and with skin effects		With use and with respiratory effects		With use and with skin and respiratory effects		P
	2001	2023	2001	2023	2001	2023	2001	2023	2001	2023	
Eugenol	8.8	20.0	76.2	63.2	8.3		3.9	12.4	2.8	4.4	0.156
Formocresol	16.0	29.6	49.7	53.2	8.3	4.4	18.2	4.4	7.7	8.4	<0.001
Formalin	23.2	54.8	43.1	35.6	8.3		17.7	5.2	7.7	4.4	<0.001
Alkaline dental X-ray developer	5.0	61.6	8.3	37.2	9.4		45.3	1.2	32.0		<0.001
Acidic dental X-ray fixer	33.1	57.6	44.2	36	10.5		6.6	1.1	5.5		<0.001
Acid etch material	13.3	24.0	66.9	66.8	16.6	7.2	1.1	0.8	2.2	1.2	<0.001
Resin-based dental restorative material	9.4	99.6	86.7	0.4	2.8		1.1				0.010
Mercury amalgam powder	9.9	0.4	66.9	94.4	5.0		6.6	5.2	11.6		0.008
Varnish solvent (ether)	19.9	46.4	54.7	50.8	3.3	1.2	16.6	1.2	5.5	0.4	<0.001

Table 5: Statistical distribution (%) of exposure type and consequence of chemicals used in the infection control among dentists in 2001 (n=184) and 2023 (n=250)

Variable	Without use		With use and without effects		With use and with skin effects		With use and with respiratory effects		With use and with skin and respiratory effects		P
	2001	2023	2001	2023	2001	2023	2001	2023	2001	2023	
Latex	7.7	25.0	54.7	45.1	34.3	24.6	1.7		1.7		0.028
Micro 10 disinfectant	10.5	32.4	75.7	57.2	9.4	10.0	0.6	0.0	3.9	0.4	<0.001
Sidex disinfectant	51.9	59.6	31.5	34.4	5.5	6.0	7.7		3.3		0.015
Savlon	42.0	74.4	47.5	24.4	6.1	1.2	2.8		1.7		<0.001
Povidone-iodine	34.8	59.6	58.6	40.0	5.5	0.4	0.6		0.6		<0.001
Bathroom soap	11.6	99.6	74.0		13.8	0.4			0.6		<0.001
Sodium hypochlorite	17.1	11.2	42.0	26.8	12.2		14.9	47.6	13.8	14.4	<0.001

2001 ($P < 0.001$). Use of chloroform solvent also did not change between 2001 and 2023 ($P = 0.699$), whereas the use of other chemical substances has significantly decreased in 2023 compared to those in 2001 ($P < 0.004$).

Among chemicals used in endo and restorative operations, the use of mercury amalgam powder has significantly increased in 2023 compared to that in 2001 ($P = 0.008$). The use of eugenol also did not change between 2001 and 2023 ($P = 0.156$), whereas the use of other chemical substances has significantly reduced in 2023 compared to those in 2001 ($P < 0.010$).

Among chemicals used in infection control, the use of sodium hypochlorite has significantly increased in 2023 compared to 2001 ($P < 0.001$). While the use of other chemical substances has significantly decreased in 2023 compared to those in 2001 ($P < 0.028$).

In 2001, skin effects were more frequently self-reported consequences among individuals exposed to acid etch material, latex, alkaline dental X-ray

developer, acidic dental X-ray fixer, bathroom soap, mercury amalgam powder, and sodium hypochlorite. Moreover, respiratory effects were more frequently self-reported consequences among people exposed to formocresol, formalin, self-cure acryl, varnish solvent (ether), chloroform solvent, alkaline dental X-ray developer, mercury amalgam powder, and sodium hypochlorite. In 2023, skin effects were more frequently self-reported consequences among persons exposed to latex and micro 10 disinfectant, and respiratory effects were more frequently self-reported consequences among individuals exposed to sodium hypochlorite.

Table 6 represents the statistical distribution of control measures among dentists in 2001 ($n = 184$) and 2023 ($n = 250$). The findings revealed that professional control measures, including education, personal protective equipment, engineering control, and several solutions, have significantly improved in 2023 compared to those in 2001 ($P < 0.001$). Furthermore, the use of gloves and masks has also significantly increased in 2023 compared to those in 2001 ($P < 0.001$). However,

Table 6: Statistical distribution (%) of control measures among dentists in 2001 (n=184) and 2023 (n=250)

Variable	2001	2023	P
Total control measures			
Education	14.1	21.6	<0.001
Personal protective equipment	16.8	25.6	
Workplace improvement	56.5	2.8	
Engineering control	1.1	1.2	
Several solutions (several above measures)	11.4	48.8	
Use of gloves			
Yes	83.7	100.0	<0.001
No	16.3	0.0	
Use of masks			
Yes	84.8	98.8	<0.001
No	15.2	1.2	
Ventilation status			
Natural	85.9	88.4	0.137
Artificial	3.8	1.2	
Both	6.4	10.4	
None	3.8	0.0	

ventilation status has not significantly changed in 2023 compared to that in 2001 ($P = 0.137$).

DISCUSSION

Exposure to chemicals is one of the most important health concerns in dentistry. Although several studies have examined some of these exposures, there is a need for a comprehensive investigation. Moreover, exposure to chemicals in dentists has altered over time because of changes in procedures, consumables, and control measures. The present study aimed to investigate the changes in chemical exposure and control measures in dental offices in Isfahan city, Iran, from 2001 to 2023.

On exposure time characteristics of dentists, the results of the present study showed that career length and work duration per day have significantly increased among participants in 2023 compared to those in 2001. While work frequency per week has significantly decreased among dentists in 2023 compared to that in 2001. In terms of exposure time, the increase in career length among dentists may lead to more experience in the use of chemicals and implementation of control measures.^[11] Furthermore, although their duration (working hours per day) has increased, the frequency (number of working days per week) has decreased. The sum of these agents can affect the exposure to chemicals.^[12]

On exposure type and control measures, the results indicated that 22 chemical substances were used

in most dental offices in 2001, and 14 chemical substances were applied in most dental offices in 2023. Although the use of some chemicals has increased or unchanged, the use of most chemicals has decreased. The results of some studies on temporal changes of exposure to occupational chemicals show that exposure levels of most chemicals have decreased over time.^[9,10] Furthermore, the results of the present study showed that professional control measures, including education, personal protective equipment, engineering control, and several solutions, have significantly improved in 2023 compared to those in 2001. Hence, the use of gloves and masks has significantly increased in 2023 compared to 2001. These improvements are consistent with reduced exposure potential. However, direct exposure measurements or incident health outcomes were not assessed. This can be because of replacing less hazardous materials with more hazardous materials, implementing stricter control measures, developing advances in dental materials and technologies, increasing employee awareness, and implementing updated national and international regulations and guidelines. For example, the use of developer/fixer chemicals and mercury amalgam has likely declined due to digital radiography and amalgam phase-downs. Technology adoption, regulatory shifts, and market availability are introduced as drivers of substitution for various materials. The extensive implementation of digital radiography, encompassing advanced sensors and imaging software, has significantly reduced reliance on traditional film-based processing methods.^[13] In addition, international agreements like the Minamata Convention on mercury have encouraged the reduction of dental amalgam containing mercury.^[14] On a commercial scale, the broader accessibility, enhanced efficacy, and greater patient preference for mercury-free restorative options – such as resin composites and glass ionomer cements – have further driven this shift in the dental profession.^[15] Moreover, Petrović *et al.* recommended several preventive strategies to reduce occupational diseases among dental technicians. These strategies include the design of standardized and optimal workplace conditions, use of local and general ventilation systems, design of workstations equipped with appropriate tools, and use of suitable personal protective equipment.^[16] Lajolo *et al.* also emphasized that sufficient awareness is essential for the execution of effective preventive strategies in oral healthcare professionals.^[17] Furthermore, it should be noted that

the increased awareness can be partly due to the coronavirus disease 2019 (COVID-19) pandemic. The results of several studies performed by Khader *et al.*,^[18] Mustafa *et al.*,^[19] and Princeton *et al.*^[20] show that the COVID-19 pandemic has increased the knowledge, attitudes, and awareness of dentists about infection control and preventive measures. The results of a study performed by Taha *et al.* showed that some patients avoid the treatment in some dental offices due to perceived cross-infection risk and concerns about the methods used by the dentists to sterilize dental instruments.^[21] These findings are consistent with the results obtained in the present study.

For the investigation of consequences due to chemical exposure, the information on skin and respiratory effects was collected through self-reported assessment from dentists. In 2001, skin effects were more frequently self-reported among individuals exposed to acid etch material, latex, alkaline dental X-ray developer, acidic dental X-ray fixer, bathroom soap, mercury amalgam powder, and sodium hypochlorite. Acidic substances cause coagulation necrosis, which results in cytotoxic effects. Alkaline substances generally exhibit greater toxicity than acids, because of their capacity to cause irreversible protein denaturation and tissue injury.^[22] These agents can provoke skin irritation, such as itching, rashes, or hives, as well as allergy symptoms.^[23] Because soap is often alkaline, it can deplete the skin's natural oils, which potentially lead to breakouts, inflammation, and irritation.^[24] Contact with amalgam has also been linked to the development of dermatitis.^[25] Sodium hypochlorite is recognized as an irritant, and there are documented reports of allergic contact dermatitis due to exposure to this substance.^[26] Moreover, based on the results of the present study, respiratory effects were more frequently self-reported among people exposed to formocresol, formalin, self-cure acryl, varnish solvent (ether), chloroform solvent, alkaline dental X-ray developer, mercury amalgam powder, and sodium hypochlorite. Formocresol, as a pulpotomy agent in dental procedures, is recognized as a chemical substance with carcinogenic potential and well-documented risks.^[27] Formalin acts as an irritant to the eyes, skin, and respiratory system. Inhalation of its vapors may result in bronchial constriction and pulmonary edema.^[28] Contact with acrylic compounds is linked to the development of asthma and other respiratory disorders.^[29] Exposure to ether can cause irritation of the respiratory mucosa, which leads to laryngeal

spasms.^[30] Inhalation of chloroform vapors may provoke irritation of the respiratory tract.^[31] Alkaline substances can diminish vigorous inspiratory efforts during respiratory failure.^[32] Respirable amalgam powder with mercury may adversely affect respiratory function.^[33] Inhalation of sodium hypochlorite can irritate the airways and lead to pulmonary edema.^[34] The results of the present study indicated that in 2023, skin effects were more frequently self-reported among individuals exposed to latex and micro 10 disinfectant, and respiratory effects were more frequently self-reported among people exposed to sodium hypochlorite. The skin and respiratory effects due to exposure to latex and sodium hypochlorite were explained. On micro 10 disinfectants, exposure to these substances can be associated with skin dryness, irritation, and itching.^[35] Several studies also introduced some chemical exposures. Lajolo *et al.* introduced some chemical hazards among dental hygienists, including exposure to NRL, composite resins, acrylic resins, and mercury.^[17] Naryal *et al.* concluded that hazardous chemicals used in clinical dentistry included mercury, powdered NRL, disinfectants, methyl methacrylate, metal alloys, silica, and N₂O.^[7] In the study of Lindbohm *et al.* also, chemicals with high exposure rates in dentistry included mercury amalgam, polymethylmethacrylate, organic solvents, and disinfectant.^[36] Most of these exposures in the present study were observed.

As a limitation, the data were collected through self-reported assessments, not chemical or clinical tests. Moreover, the study was performed with a cross-sectional design, not a longitudinal design. However, the sample size was calculated based on the study population in 2001 and 2023, and an attempt was made to select appropriate samples from the population through simple random sampling. Moreover, it was tried that the differences were decreased through inclusion criteria, including the presence of a dentist in the office, office location within Isfahan, and the willingness of the dentists to cooperate in the research. The exclusion criteria also included inaccuracy in completing the checklist. Furthermore, data related to age in 2001 was not available.

CONCLUSION

This study showed that the use of most chemical substances in dental offices decreased in 2023 compared with 2001. Moreover, professional control

measures, including education, personal protective equipment, and engineering controls, improved substantially over time. Hence, these changes have been accompanied by a reduction in self-reported effects. These findings can be used by policymakers to perform regular monitoring of chemical use, plan the implementation of control measures, and strengthen occupational health regulations for the continued adoption of safer materials and technologies in dental practice. Moreover, the results are useful for dentists who are encouraged to maintain and enhance the implementation of effective control measures and to substitute hazardous substances with safer alternatives.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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