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ORIGINAL RESEARCH

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Assessment of growth & development, dental caries, and dental development in children with congenital heart disease

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Abstract

Background: Congenital heart disease (CHD) may affect children's growth and development, as well as dental health. Although oral conditions in children with CHD have been studied, the impact of CHD on dental development and dental age (DA) remains limited. This study aimed to investigate the relationship between growth-development, dental caries, and dental age in children with CHD and compare them with healthy children. **Methods**: A cross-sectional study was conducted involving 108 children diagnosed with CHD and 111 healthy controls. s. Chronological age (CA) was calculated from clinical records. DA was estimated using Cameriere's European formula based on digital panoramic radiographs. Clinical data including plaque index (PI) and dental caries indices (dmft/dft/DMFT) were collected. Statistical analyses included Mann-Whitney U and Spearman correlation tests ($\alpha = 0.05$). **Results**: There was no significant difference in CA or dental caries scores between groups ($p > 0.05$), but PI scores were significantly higher in the CHD group ($p < 0.001$). The mean DA in the CHD group (9.2 ± 2.5) compared to controls (10.1 ± 2.5) ($p = 0.009$). No significant difference was found in DA between cyanotic and acyanotic CHD types. **Conclusions**: Children with CHD showed delayed dental age despite having similar chronological age, BMI, and dental caries scores compared to healthy peers. CHD should be considered a potential factor in assessing dental development, especially in the context of growth and systemic disease.

Keywords

Congenital heart disease; Dental age; Growth & development

1. Introduction

Congenital heart disease (CHD) is described as the morphologic malformation of the heart and intrathoracic great vessels during intrauterine development and seen in 0.5–0.8% of all live births [1, 2]. Cyanotic patients constitute 15% of all CHD cases [3, 4]. Recent developments in cardiovascular imaging techniques and diagnostic methods have provided early detection and treatment options for children with CHD and increased their rates of survival [5]. Improving the quality of life of children experiencing CHD by eliminating their oral health problems through effective diagnostic procedures and preventive dentistry is also very important.

CHD-affected children are subjected to several oral health risk factors [6, 7]. As parents tend to focus primarily on their children's more significant medical issues, oral health care may be overlooked [8]. Children experiencing CHD have been reported to be more frequently affected by carious lesions [3], dental plaque, and gingivitis [9] and thus to have worse oral health than their healthy counterparts.

Negative effects of CHD on growth and development have previously been remarked, severe growth retardation was especially reported in the cases involving right-to-left shunting (RLS) and pulmonary hypertension and also in cases of prominent cardiac insufficiency and cyanosis [10]. Although the tissues are sufficiently perfused in patients with CHD, hypoxia occurs when the oxygen supply required for tissues drops below the physiological levels. The body's response to this pathophysiological condition includes changes such as neovascularization and red blood cell generation [11]. In view of the fact that exposure to chronic hypoxia affects the whole metabolism, its impact on dental development becomes another area of interest. Yet, sufficient data is not available in the literature on how dental development and dental age (DA) of the children with CHD are impacted.

Several assessment methods are used for determining chronological age (CA), one of which is the skeletal maturity evaluation [12]. However, skeletal maturity assessment for bone age measurement can be misleading since it may be affected by several environmental factors. Thus, a DA assessment method based on analyzing tooth development, which is less vulnerable to contextual factors (regulated by

genetics) would be a more appropriate technique for the children [13–15]. Nonetheless, growth & development, nutrition, and dental caries should also be considered as important environmental parameters that may influence dental development [16].

Age estimation is of crucial importance in forensic dentistry, orthodontics, and pediatric endocrinology with different methods of assessing dental and skeletal maturity often used [17]. Several odontological estimation methods assessing tooth eruption, exfoliation of primary teeth, and stages of dental development are used for determining CA and several studies have also been conducted on estimating DA of patients with different systemic disorders [18–20]. However, there are a limited number of studies examining dental development and DA in children with CHD [21].

Many factors contribute to the development of dental caries. The interaction of environmental and genetic factors such as the effects of oral microbiota, dietary habits, oral hygiene, saliva composition, and tooth structure play a role in the formation and progression of caries [22]. Parents with children with systemic diseases often focus on the systemic disease and neglect oral health and risk factors [23]. There are studies in the literature showing that children with CHD have poorer oral health [3, 9, 23]. In the present study, dental development was evaluated in children with CHD compared to healthy patients and dental caries were also evaluated. In addition, to date, no study has been published that evaluates CHD, growth-development, dental caries and tooth development all together. Based on this, this research hypothesized that the oral and dental health levels and dental development of children with CHD would not differ from healthy children.

With the intention of filling the gap within the literature, this study aimed to assess the impact of CHD, growth and development, and dental caries on dental development in children and also to compare the obtained results with those of healthy children.

2. Material and method

This study was conducted in accordance with the Ataturk University Faculty of Medicine Ethics Committee approval (Approval Date: 26 December 2019; Session No: 08, Decision No: 52) and guidelines of the Declaration of Helsinki. Prior to the study, informed consents in writing were obtained from all parents.

2.1 Patient selection

The present cross-sectional study consisted of 219 participants. This study was conducted between July and December 2022. The study group included patients who were previously diagnosed with CHD and followed-up at the department of pediatric cardiology in Ataturk University's Faculty of Medicine. CHD was detected through cardiac imaging and evaluation (experienced pediatric cardiologists performed transthoracic echocardiography on all patients whereas patients requiring advanced diagnostics and treatment additionally underwent transesophageal echocardiography, thoracic computed tomography, cardiac magnetic resonance imaging and right heart catheterization). Of the 108 patients in the study group, 21 were diagnosed with cyanotic CHD while acyanotic CHD was detected in 87. The control group involved 111 healthy children aged 5–15 years who presented to the Department of Pedodontics in Ataturk University's Faculty of Dentistry. When selecting the control group patients, care was taken to ensure similar chronologic age and gender distribution with the study group.

2.2 Exclusion criteria

Within the study, a number of factors that may affect dental development and tooth age were observed. Children with a history of previous orthodontic treatment or appliances, hypodontia in the left mandible excluding permanent third molars, extracted or missing teeth, deep carious lesions, restorations, apical lesions, root canal treatment, congenital anomalies, trauma in the relevant areas, as well as Class II and III malocclusion, no orthopantomography (OPG), and children who did not want to participate were excluded. Also excluded were systemic disorders that may affect growth and development and consequently affect tooth development and tooth age. These included disorders of bone metabolism, thyroid disorders, adrenal hormone disorders, systemic diseases, cirrhosis, chronic renal failure (glomerular filtration rate (eGFR) <30 mL/min/1.73), gonadal disorders, disorders of parathormone and calcium metabolism, vitamin D deficiency, and patients under corticosteroid therapy, taking antiepileptic drugs and heparin, receiving chemotherapy, and patients with a current or previous history of medication affecting bone.

2.3 Inclusion criteria

The study group included volunteer patients diagnosed with CHD who were followed up and/or their parents. The control group included children in the same age group without systemic disease and/or whose parents allowed their participation.

2.4 Determination of CA

The CA of each patient was calculated using the formula "date of the radiograph-birthdate recorded on the official records/365.25" in the decimal system in Excel 2018 (Version 16.78.3, Microsoft, Redmond, WA, USA) [24, 25]. In addition to chronological age, gender information was also recorded.

2.5 Determination of DA

Based on the measurements made on digital OPGs, DA of the patients were calculated using the Cameriere-EU formula [13]. In this methodology, after measuring the open apices and root lengths of the left mandibular permanent teeth, DA was estimated by placing the obtained values in Cameriere's EU formula. All measurements were made using a computer image processing software ImageJ 1.53 V. (National Institutes of Health and the Laboratory for Optical and Computational Instrumentation-LOCI, University of Wisconsin, Madison, WI, USA), onto which all digital OPGs were loaded. In accordance with Cameriere *et al.* [13], the number of mature teeth with closed apices were counted and abbreviated as N_0. For immature teeth with open apices, distance between

the inner sides of the apex was measured in single-rooted teeth (A_i, i = 1, ..., 5) and in multiple-rooted teeth, the sum of the distances between the inner sides of the two apices was calculated (A_i, i = 6, 7). In order to minimize the probable magnification and angulation errors on the OPGs, measurements were divided by tooth length (L_i, i = 1, ..., 7). The calculation for the X_5 value was made by dividing A_5 by L_5 for the second premolars. And finally, DA was assessed by placing the obtained values in Cameriere's formula (EU) as follows: Age = $8.387 + 0.282 \times g - 1.692 \times X_5 + 0.835 \times N_0 - 0.116 \times s - 0.139 \times s \times N_0$ (Gender (g) = 1 for males and 0 for females and $s = \sum A_i/L_i$).

2.6 Data collection

2.6.1 Clinical cardiac evaluation

Based on their latest echocardiographic (ECG) assessments, child patients with CHD were categorized in parallel with Table 1, which was formed in accordance with the guidelines published in Haas *et al.*'s [26, 27] article. A pediatric cardiologist reviewed the medical records of each patient to determine whether a transcatheter or surgical repair had previously been done. If such repairs had been formerly performed, the surgery date was noted, and the presence of any hemodynamically significant cardiac issue was verified during oral examinations.

TABLE 1. Classification of CHD and patient distribution by the types of CHD (n (%)).

	n (%)
Left-to-right (LRS) CHD	
Hemodynamically insignificant	24 (25.5)
Hemodynamically significant	32 (34.0)
Right-to left (RLS) CHD	
Lesions with high pulmonary blood flow	6 (6.4)
Lesions with low pulmonary blood flow	15 (16.0)
CHDs involving stenosis	
Hemodynamically significant	9 (9.6)
Hemodynamically insignificant with stenosis	8 (8.5)

CHD: Congenital heart disease.

Peripheral oxygen saturation (SPO_2) levels of the patients were monitored with a pulse oximeter (Nellcor^{TM} Bedside SPO_2 Patient Monitoring System, Medtronic-Minneapolis, MN, USA) and any medication used was also recorded. SPO_2 $\leq$92% on room air was recorded as significant for low oxygen saturation [26]. Demographic and clinical data were obtained during routine check-ups.

Presence of aortic blood flow rate >2 for ventricular septal defects and >1.5 for atrial septal defects, typical murmur of patent ductus arteriosus or left ventricular volume overload in ECG assessments of the CHD patients with LRS was regarded as hemodynamically significant heart disease. All cyanotic CHDs were accepted as hemodynamically important. Furthermore, in CHD with stenosis, presence of treatment requiring criteria was also considered as hemodynamically important [27, 28].

2.6.2 Type of data collection

Study data were obtained using two medical examination forms. The first was completed by a pediatric cardiologist in the Department of Pediatric Cardiology at Ataturk University's Faculty of Medicine and contained ECG findings, SPO_2 scores, history of surgical operations and medication use, and presence of additional diseases. The second form was completed in the Department of Pedodontics at Ataturk University's Faculty of Dentistry by a pediatric dentist and included demographic information such as age and gender, physical information such as height and weight, and indices for plaque index (PI) and decayed, missing, filled teeth (dmft/dft/DMFT) [29, 30].

Heights and weights of the participating children were measured with a sensitive digital body weighing scale (Goldmaster GM-7175W, Zhejiangang Shunkang Technology Industry Co. Ltd., Ningbo; China). These measurements were then used to calculate their body mass indices (BMI). Children were weighed barefoot and wearing light clothes. Their heights were measured while they were standing against a wall with their heads, shoulders, hips, and heels oriented in a straight line and their heads aligned in the Frankfort horizontal plane (eye-ear plane).

Percentile values of the anthropometric data obtained from the study groups were determined using the reference values for Turkish children presented by Neyzi *et al.* [31].

2.7 Calibration

Test-retest was applied to investigate whether the re-measured values of the same variables belonging to the same individuals were similar. The correlation coefficient between the initial measurement values and the re-measurement values was found to be above the minimum value of 0.70 ($p < 0.05$, r: 0.980). As a result, it can be said that the measurements were stable and continuous.

2.8 Statistical analysis

Descriptive statistics were expressed as count, mean, standard deviation, minimum and maximum. The Shapiro-Wilk's test was used for assessing the assumption of normality whereas the Mann Whitney U test was performed to compare the differences between the means of independent variables in the groups without assuming normality. Relationships between two categorical variables were analyzed with Pearson's Chi-Square test when estimated sample size (expected value >5) was met. Spearman's correlation test was performed to assess any relationships between the continuous variables that did not follow normal distribution. All statistical data were analyzed with IBM SPSS 25 (v. 25.0; IBM Corp., Armonk, NY, USA).

Although the existing literature was reviewed for similar research articles for modelling on the sample size, no suitable study was found, thus, a minimum sample size of 105 was estimated for each group at a significance level of; $\alpha = 0.05$, standardized effect size of $d = 0.50$ (medium size), and a theoretical power of $p = 0.95$. Before the study commenced, sample size was estimated using G*Power software (v.3.1.9.2; Windows, Heinrich-Heine-Universität, Düsseldorf, NRW, Germany) at a

confidence level of 0.95.

3. Results

The study group consisted of a total of 108 pediatric patients (49 female and 59 male), while the control group included 111 patients (61 female and 50 male). There was no statistically significant relationship between the gender distributions of the participating children ($p = 0.137$). Regarding the mean chronological age, no significant difference was found between the study (9.6 ± 2.8) and control (10.3 ± 3.0) ($p = 0.137$) groups. And no statistically significant difference was observed between the mean CA by dentition stages of the children involved in the study ($p = 0.591$). The study group included 21 cyanotic and 87 acyanotic patients (19.4% and 80.6%, respectively). Patient distribution by CHD types is given in Table 1.

No significant difference was found between the study and control groups in terms of percentiles for the mean height, weight, and BMI ($p = 0.965$, 0.846 and 0.490, respectively). As shown in Table 2, there was no significant difference between the study and control groups regarding dental caries index scores (dmft/dft/DMFT) in the dentition stages. However, a statistically significant difference was observed between the PI scores of these groups ($p < 0.05$). It was observed that children with better PI scores were mostly in the control group while those with poorer scores tended to be in the study group.

A height correlation was detected between the CA and DA scores in study ($p < 0.001$, r: +0.950) and control ($p < 0.001$, r: +0.955) groups. CA and DA scores of the patients were found to be quite similar.

The mean DA scores of the children with CHD (9.2 ± 2.5) were found to be significantly lower than the control group (10.1 ± 2.5). The difference between DA and CA scores (DA-CA) was found to be higher in the study group, although it was not statistically significant (Table 3).

No significant relationship was found between the type of CHD and DA in the study group ($p = 0.630$). In terms of DA, there was no significant difference between acyanotic and cyanotic CHD patients in the study group ($p = 0.247$). No correlation was observed between SPO_2 and DA in the children affected by CHD ($p = 0.070$).

A significant difference was determined between the mean DA scores of the participants by gender in the control group ($p < 0.05$) in which mean DA scores of male patients were higher than those of female patients. In the study group, there was no significant difference between genders in terms of CA/DA and DA-CA scores ($p > 0.05$) (Table 4).

4. Discussion

Local and systemic factors such as, diseases, traumas, chemotherapy or radiotherapy may impact dental development and odontogenesis at any time before the completion of dental development [32, 33]. There are numerous studies [9, 21, 34–38] examining oral and dental health of children with CHD however, research investigating their dental development are very limited. Thus, the aim of the present study was to evaluate the impact of CHD, growth and development, and dental caries status on dental development in children and also to compare the obtained results with those of the healthy children to help address the gap in the literature.

Considering the results of this study, the presented hypothesis was partially rejected because the chronologic age of children with CHD was similar to that of healthy children, but their DA was older, and the PI value was higher in the CHD group. However, since the dental caries scores and BMI values were similar in both groups, the hypothesis was partially accepted.

Obtained data on dental caries prevalence among CHD-impacted children differ from study to study. There are many studies reporting that children experiencing CHD had higher, similar, and although not statistically significant, lower dental caries prevalence than the healthy children [4, 34–38]. The present study determined similar dental caries index scores for both the study and control groups (Table 2). Children impacted by CHD are known to be more susceptible to infective endocarditis than healthy children [39]. Although the control group of the present study consisted of healthy children admitted to the clinic with high scores of DMFT/dmft, similar DMFT/dmft scores observed in the study group with CHD-affected children posed a higher risk of infective endocarditis. In this context, regular dental examinations of children with CHD should be performed and preventive applications should be carried out.

Dental caries status is an important parameter in DA estimation [16]. In addition, growth and development [40] and systemic disorders [18–20] should also be considered. In this study, the presence of dental caries was also taken into

TABLE 2. Distribution of dental caries indices, PI scores and percentiles by the groups.

	Study group (Mean. ± S.D.)	Control group (Mean. ± S.D.)	*p*
dmft (Primary dentition)	6.5 ± 3.7	8.0 ± 5.1	0.590
DMFT/dft (Mixed dentition)	5.2 ± 3.0	4.8 ± 3.1	0.480
DMFT (Permanent dentition)	3.4 ± 2.1	4.8 ± 3.0	0.076
PI	1.4 ± 0.7	0.8 ± 0.7	0.001*
Height percentile	50.0 ± 36.0	50.0 ± 34.0	0.965
Weight percentile	44.2 ± 32.1	46.1 ± 31.8	0.846
BMI percentile	49.6 ± 35.0	45.0 ± 32.2	0.490

*S.D.: Standard Deviation; dmft: decayed, missing, filled teeth; PI: plaque index; BMI: body mass index. *p < 0.05.*

TABLE 3. Distribution of mean CA, DA and DA-CA scores in the study and control groups.

Group	n	Min.–Max.	Mean. ± S.D. (M)	*p*
CA				
Study	108	5.0–15.8	9.6 ± 2.8 (9.3)	0.137
Control	111	5.3–15.8	10.3 ± 3.0 (10.6)	
DA				
Study	108	2.3–13.6	9.2 ± 2.5 (9.2)	0.009*
Control	111	4.7–14.0	10.1 ± 2.5 (10.3)	
DA-CA				
Study	108	−2.8–1.7	−0.4 ± 0.9 (−0.2)	0.069
Control	111	−3.1–1.9	−0.18 ± 1.0 (−0.1)	

*Mann Whitney U. S.D.: Standard Deviation; DA-CA: Dental age-chronologic age; Min.: Minimum; Max.: Maximum; M: Median. *p < 0.05.*

TABLE 4. Distribution of mean CA, DA and DA-CA scores by gender in the study and control groups.

Group	Gender	n	Min.–Max.	Mean. ± S.D. (M)	*p*
Study					
CA	Girl	49	5.0–15.8	9.8 ± 2.8 (9.3)	0.632
	Boy	59	5.0–15.5	9.5 ± 2.8 (9.3)	
DA	Girl	49	4.9–13.6	9.4 ± 2.5 (9.6)	0.677
	Boy	59	2.3–13.3	9.1 ± 2.4 (9.1)	
DA-CA	Girl	49	−2.8–1.2	−0.4 ± 0.9 (−0.2)	0.907
	Boy	59	−2.8–1.7	−0.4 ± 1.0 (−0.2)	
Control					
CA	Girl	61	5.3–15.7	9.8 ± 2.9 (9.4)	0.071
	Boy	49	5.5–15.8	10.8 ± 3.1 (11.5)	
DA	Girl	61	4.7–13.6	9.6 ± 2.5 (9.9)	0.037*
	Boy	49	6.2–14.0	10.6 ± 2.5 (10.7)	
DA-CA	Girl	61	−3.1–1.9	−0.14 ± 1.05 (0)	0.526
	Boy	49	−2.1–1.5	−0.2 ± 1 (−0.2)	

*Mann Whitney U. S.D.: Standard Deviation; DA-CA: Dental age-chronologic age; Min.: Minimum; Max.: Maximum; M: Median. *p < 0.05.*

consideration for the estimation of DA in the children with CHD (Table 2).

Similarly, Bodrumlu *et al.* [16] reported that dental caries had a negative impact on dental development. They evaluated the OPGs of 300 children affected with early childhood caries (ECC) using Demirjian's method and determined a slower dental development in children with ECC than control children. They also remarked that the DA-CA scores of the children with ECC were significantly lower than those of the healthy children [16]. Additionally, in their study assessing the impacts of ECC on growth, development, and quality of life, Eyisoy *et al.* [41] reported that ECC had adversely affected growth and development. In the present study, similar DMFT/dmft scores found in both CHD-impacted and healthy children groups suggested that tooth development might have been similarly affected by the dental caries in both groups.

Different research has reported varying results regarding the PI, which was another parameter evaluated in the present study [3, 4]. There are many previous studies expressing that children with CHD had PI scores equal to or greater than those of healthy children [3, 4, 21, 38, 42]. Similarly, PI scores within the present research were found to be significantly higher in children with CHD than the control group ($p < 0.001$). Recent studies revealed that children with CHD developed early atherosclerosis and had a high risk of vascular diseases and complications when they reached adulthood [43, 44]. This increasing risk among children was also associated with elevated levels of inflammatory mediators following severe dental plaque and prolonged gingivitis [45]. In this aspect, higher PI scores observed in the children with CHD created a high risk of developing heart diseases.

DA estimation provides guidance on the diagnosis and treatment planning of systemic disorders. Much research has been conducted on assessing DA estimation in different populations with different systemic diseases [18–20]. In the present study, Cameriere's methodology was selected as it had been previ-

ously reported to be more suitable [46] for estimating DA in Turkish children. Unlike the present study, Cantekin *et al*. [21] determined the DA of CHD patients using Demirjian's method and comparable to the results of this present research, they also determined that DA scores were lower in the group with CHD patients.

In the present research, although CA was nearly identical in both the study and control groups, DA was found to be lower in the study group (p = 0.009, Table 3). A higher DA-CA score was determined in the study group however statistically insignificant (p = 0.069, Table 3). This research also observed a statistically significant difference between the mean DA scores of the participants by gender, which might be associated with the higher CA scores of the males in the control group.

The fact that DA was lower in the CHD group compared to the healthy group in the current study may be important for forensic dentistry. Considering the results of this study, it will be important to question the systemic disease status (*i.e.*, CHD for example) of individuals when DA should be determined for forensic dentistry investigations.

There are previous studies in the literature evaluating the effect of BMI on tooth development [40, 47]. Hilgers *et al*. [47] previously evaluated BMI percentiles and found that tooth development accelerated as BMI increased. In the present study, height, weight, and BMI percentile values were similar in both groups (Table 2). The fact that growth and development may affect tooth development were similar in both the study and healthy group may be considered to have a positive effect on the present study in terms of evaluating the effect of CHD on tooth development in isolation.

The present study showed no statistically significant correlation between hemodynamically important heart diseases and DA in the study group. Thanks to recent evolutions in intrauterine diagnostics and treatment modalities, children with CHD have an opportunity for early treatment [5]. In the present study, no impact of cyanosis and other CHD types were observed on the dental development, leading to the belief that early-term surgical interventions/treatment procedures performed on these children consequently minimized the negative effects of cyanosis.

The present study is significant as being one of the few evaluating the impact of CHD on dental development using a DA estimation method and also investigating the dental caries indices, which have been previously reported to affect DA. In addition, height, weight, and BMI percentile values that may be related to jaw and tooth development were also examined. The strength of this research for the literature is that the parameters that may affect tooth development were evaluated together when evaluating DA for CHD and healthy groups with similar chronological age.

There are some limitations of this study that should be taken into consideration when planning future studies. Firstly, the number of patients was limited and accordingly the distribution to disease groups was not balanced. Secondly, the study was regional in nature. Thirdly, the control group was composed of children with high caries prevalence who came to the pedodontics clinic for treatment.

5. Conclusions

In this study, dental caries, BMI, and CA parameters that may affect tooth development were found to be similar in the CHD and healthy groups. Despite these similarities, it was observed that tooth age was older in the CHD group. In addition, PI values were higher in the CHD group. The results of this study are considered important for orthodontics, pediatric dentistry, and forensic dentistry.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on request from the corresponding author.

AUTHOR CONTRIBUTIONS

FS and SŞD—have given substantial contributions to the conception or the design of the manuscript. FS—acquisition, analysis and interpretation of the data. SŞD—revised it critically. All authors have participated to drafting the manuscript. All authors read and approved the final version of the manuscript. All authors contributed equally to the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted in accordance with the Ataturk University Faculty of Medicine Ethics Committee approval, (Approval Date: 26 December 2019; Session No: 08, Decision No: 52) and guidelines of the Declaration of Helsinki. Prior to the study, informed consents in writing were obtained from all parents.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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