RESEARCH

Dental arch form and arch dimensions among a group of Egyptian children and adolescents

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Abstract

Background: Growth and development of the dental arch is considered a continuous and complex biological process. During transition from primary to mixed then to permanent dentition, dental arch form, length and width vary, due to tooth movement and vertical growth of alveolar process. These naturally occurring changes, which happen in untreated individuals, have been used as a comparative standard to assist in diagnosis and treatment planning of children with malocclusion. Therefore, the aim of the current study was to analyze dental arch dimensions in Egyptian children and adolescents with normal occlusion in primary, mixed, and permanent dentitions as well as detection of the most common forms of the dental arches among a group of Egyptian children and adolescents.

Results: Results showed that lower and upper arch lengths showed increase during transition from mixed to permanent dentition. A small increase in lower anterior arch length was recorded during transition from primary (4.63) to mixed dentition (4.70), while reduction of upper anterior arch length was observed during transition from primary (8.35) to mixed dentitions. An increase in anterior arch length was observed in both arches during transition from mixed to permanent dentitions (from 4.70 to 5.42 in the mandible and from 7.92 to 9.90 in the maxilla). Arch perimeter, intercanine width, intermolar width increased in the upper and lower arches during transition between dentition till reaching the permanent dentition. It was also found that the ovoid arch form (58%) and square arch form (29%) were the most prevalent among Egyptian children and adolescents followed by the tapered arch form (13%).

Conclusions: Dental arch measurements of Egyptian children and adolescents can be used as a guide for treatment planning of Egyptian children and can be used in further studies to provide standard values for the arch dimensions of the Egyptian children. Regarding the arch form, the ovoid arch form was the most common among the Egyptian population followed by the square while the tapered arch form was the least common one.

Keywords: Arch length, Intercanine width, Intermolar width, Arch form, Egyptian children

Background

Growth and development of the dental arch are considered continuous and complex biological processes. It includes three-dimensional changes in width, length and height of the arch. These changes vary with age in measurements of each parameter and magnitude of change through each stage of growth and development (Yang et al. 2019).

The changes in facial dimensions occur in vertical and sagittal dimensions throughout growth of children. During transition from primary to mixed then to permanent dentition, dental arch form and width vary due to tooth movement and vertical growth of alveolar process (Slaj et al. 2003; Rajbhoj et al. 2021).

These naturally occurring changes, which happen in untreated individuals, have been used as a comparative

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standard to assist in diagnosis and treatment planning of children and adolescents with malocclusion (Carter and Namara 1998; Thilander 2009).

Researchers demonstrated that each human ethnic group displays dental arch characteristics and measurements unique to them. Comparing between Caucasoid, Mongoloid, Negroid, and Australoid, clarified the presence of basic differences in dental arch size and shape between the different populations (Lavelle et al. 1971), at the same time differences in the arch dimensions between Mongoloid race and Dravidian race children were quite clear and recorded by (Smitha et al. 2020) which clarify the necessity of having baseline records for every population.

Dental records in the form of casts have a vital role in critical analysis and treatment planning for children, not only by providing a 3-dimensional view of the dental occlusion, but also they allow precise measurements to be carried out (Hassanali and Odhiambo 2000; Shafique et al. 2021). These measurements help in diagnosis, predicting the risk of crowding for children and indicate the various treatment modalities. Among these important measurements, the sum of mesiodistal width of both maxillary and mandibular teeth, determination of Bolton's ratios, space available, space required, arch width, length, and perimeter (Selmani and Gjorgova 2015; Yang et al. 2019).

It is claimed that arch length and width are correlated to arch perimeter in both the mandibular and maxillary arches, which subsequently affect the risk of crowding among children and adolescents (Al-Khatieb et al. 2012; Al-ansari et al. 2019).

Appropriate arch form is crucial to achieve functional, stable and esthetically pleasing dentition, and different factors have been stated to affect the arch form, like the ethnic factor, growth of bone, eruption of teeth, different types of malocclusion, habits and pressure of oral musculature. At the same time, arch form is considered an important criterion for ideal occlusion (Kook et al. 2004). Since then, researchers had emphasized the importance of determining the prevalence of the different arch forms among different populations.

Few studies were performed among Egyptian children to provide base line records for the arch dimensions and arch form. Therefore, the aim of the current study was to analyze dental arch dimensions in a group of Egyptian children and adolescents with normal occlusion in primary, mixed, and permanent dentitions as well as detection of the most common forms of the dental arches among Egyptian children and adolescents.

Methods

Ethical approval

The study was approved by the Medical Research Ethics committee of the NationalResearch Centre of Egypt in accordance with the principles of declaration ofHelsinki and the ethical approval number was 16-343. All children who participatedin the current study, their guardians signed an informed consent.

Study sample

The current study was performed as a part of the project of Orthodontic and Pediatric Dentistry Department, National Research Centre—Egypt. Clinical diagnosis was performed as well as impressions for school children aged 4–14 years at Al-Fayoum Governorate.

The sample size was calculated based upon results of the study performed by El-Yazeed and Abou-Zeid (2013). Casts for all children included in the project were examined and evaluated according to the following inclusion and exclusion criteria to select the best casts that suit the current study.

Inclusion criteria

- Class I molar relationships (in casts with mixed or permanent dentition)
- Well-aligned teeth in upper and lower dental arches
- Symmetrical casts

Exclusion criteria

- Presence of any fractured tooth or badly decayed tooth
- Presence of congenital defects or deformed teeth.
- Presence of any fixed prosthetic appliance
- Presence of cleft lip or palate
- Presence of supernumerary, missed, linguo-versed, bucco-versed, or transposed teeth
- Casts with air bubbles, cracked or fractured casts
- Presence of crossbite or scissors bite
- Presence of anomaly in size or shape of teeth
- Presence of interproximal caries or restorations that can affect the measurements.

The casts were classified according to the dentition stage into one of the following three categories.

- **Deciduous dentition** (all deciduous teeth were fully erupted), $n = 72$ pair of casts
- **Mixed dentition (**all permanent incisors and first molars fully erupted, presence of deciduous canines

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and molars, ongoing eruption of permanent canines and/or premolars), $n = 156$ pair of casts

- **Permanent dentition** *(*all permanent teeth fully erupted with exception of third molars), $n = 84$ pair of casts

Measurements of dental arch dimensions

The casts were traced using TracerNet (Nile Delta software, version II) after capturing photographs of the casts and importing them to the software. The calibration of the casts was performed in both horizontal and vertical dimensions using a millimeter ruler. The magnification of the ruler in the two axis was measured, and the casts' magnification was calculated. Maximum accuracy was achieved when the two scales were perpendicular. The points needed for every measurement were marked by two well-trained operators and the software automatically determined the measurements in millimeters, and the average of the two readings was considered.

The total arch length (TAL) was calculated by measuring the vertical distance from the incisal point perpendicular to a line joining the mesiolingual cusp tips of maxillary first permanent molars and the mesiobuccal cusp tips of mandibular molars (Fig. 1).

The *anterior arch length (AAL)* was evaluated through the perpendicular distance from the line which connects the central incisors up to the canine's line.

Posterior arch length (PAL) was calculated through the difference between the total arch length and the anterior segment length of the arch.

Intercanine width (ICW) was determined by measuring the distance between the cusp tips of the right and left canines.
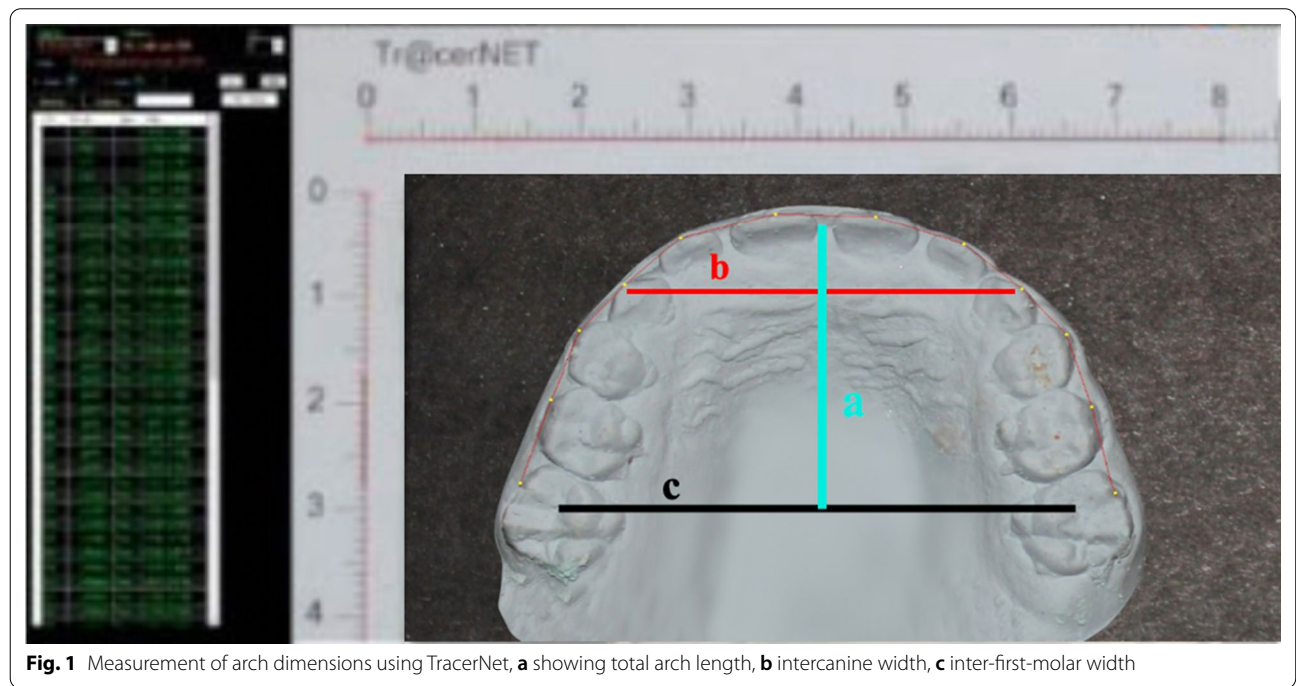
Inter-first-molar width was evaluated by the distance between the central sulcus of the right and left first molars (Azlan et al. 2019).

Arch perimeter (AP) was calculated by measuring the distance between the mesiobuccal cusp tip of the first molar on one side passing through cusps tips and incisal edges to its corresponding on the other side (Louly et al. 2011, Kareem et al. 2011, Alam et al. 2014, and Shahid et al. 2015).

Each dental cast was classified into ovoid, square, or tapered form by superimposing the three templates and then choosing the one that best fit the clinical points and the contact points on the cast.

Statistical analysis

Data were analyzed using IBM SPSS version 18.0 (IBM Corporation, New York, USA). Simple descriptive statistics were used to define the characteristics of the study variables through a form of counts and percentages for the categorical and nominal variables; continuous variables were presented by mean and standard deviations. Independent sample t-test was used to determine any statistically significant differences between males and

Fig. 1 Measurement of arch dimensions using TracerNet, **a** showing total arch length, **b** intercanine width, **c** inter-first-molar width

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females for each measurement, value of p < 0.05 was considered the level of significance.

Results

Patients whose casts fulfilled the previously mentioned inclusion and exclusion criteria were included in the current study, to analyze dental arch dimensions in children and adolescents with normal occlusion in primary, mixed and permanent dentitions as well as detection of the most common forms of dental arches among Egyptian children.

Results showed that total lower and upper arch lengths showed increase during transition from mixed to permanent dentition. The increase in total lower arch length was from (29.19) in mixed dentition to (30.42) in permanent dentition. Likewise, the maxillary total arch length showed an increase from (32.86) in mixed dentition to (35.74) in permanent dentition (Table 1).

A small increase in lower anterior arch length was recorded during transition from primary (4.63) to mixed dentition (4.70), while reduction of upper anterior arch length was observed during transition from primary (8.35) to mixed dentitions (7.92). Then, an increase in anterior arch length was observed in both arches from mixed to permanent dentitions (from 4.70 to 5.42 for mandible and from 7.92 to 9.90 for maxilla) (Table 1).

A small increase in mandibular intercanine width was observed during transition from primary dentition (23.38) to mixed dentition (24.98), and then, marked increase was noticed during transition to permanent dentition (28.01), while for maxillary intercanine width, the increase in upper intercanine width readings was minimal from primary (30.70) to mixed dentition (30.88) but marked increase was observed during transition to the permanent dentition (35.18).

As regarding the intermolar width, it showed an increase from mixed to permanent dentitions in both

Table 2 Mean, standard deviation of upper and lower intercanine width and inter-first-molar width in primary, mixed, and permanent dentitions

		Deciduous	Mixed	Permanent
Upper intercanine width	Mean	30.70	30.88	35.18
	SD	2.40	2.32	2.22
Lower intercanine width	Mean	23.38	24.98	28.01
	SD	2.28	1.88	2.43
Upper inter-first-molar width	Mean	–	43.61	46.95
	SD	–	3.71	3.13
Lower inter-first-molar width	Mean	–	39.20	42.74
	SD	–	3.04	2.74

arches (from 43.61 to 46.95 for maxillary arch and from 39.20 to 42.74 for mandibular arch) (Table 2).

Regarding arch perimeter in both mandible and maxilla, an increase in arch perimeter was observed through transition from primary to mixed then permanent dentitions. In the maxillary arch, arch perimeter increased from 72.79 in primary dentition to 88.29 in mixed dentition and it reached 97.81 in permanent dentition. While in mandibular arch, arch perimeter increased from 81.19 in deciduous dentition to 92.54 in mixed dentition, and then, it markedly increased to 104.74 in permanent dentition (Table 3).

Difference between the two genders for all dental arch dimensions measured revealed that males had higher values than females for all arch parameters but these differences were only significant for lower intercanine width (p < 0.05) (Table 4).

Regarding dental arch form, it was found that three forms were predominating among the Egyptian population, these forms are as follows: ovoid, square and tapered arch forms, while statistical analysis showed that the ovoid form (58%) and square form (29%) were more prevalent than tapered arch form (13%) (Fig. 2).

Table 1 Mean and standard deviation of total arch length and anterior arch length in upper and lower arches in deciduous, mixed, and permanent dentitions

		Deciduous	Mixed	Permanent
Upper TAL	Mean	–	32.86	35.74
	SD	–	7.97	12.87
Lower TAL	Mean	–	29.19	30.42
	SD	–	6.88	9.76
Upper AAL	Mean	8.35	7.92	9.90
	SD	3.62	2.31	5.00
Lower AAL	Mean	4.63	4.70	5.42
	SD	1.90	1.75	2.17

Table 3 Mean, standard deviation of arch perimeter in upper and lower arches in primary, mixed, and permanent dentitions

		Deciduous	Mixed	Permanent
Upper arch perimeter (AP)	Mean	81.19	92.54	104.74
	SD	11.78	10.51	22.61
Lower arch perimeter (AP)	Mean	72.79	88.29	97.81
	SD	15.57	10.33	20.41

Table 4 Showing t test for equality of Means for the two genders

	t	df	P
Lower ICW	2.052	76	**0.044**
Upper ICW	1.626	74	0.108
Lower inter-first-molar width	1.610	55	0.113
Upper inter-first-molar width	1.260	51	0.213
Lower TAL	1.384	55	0.172
Upper TAL	1.303	28.882	0.203
Upper AAL	0.403	71	0.688
Lower AAL	1.023	70	0.310
Lower AP	1.039	77	0.302
Upper AP	0.736	77	0.464

Bold value indicates statistically significant difference between males and females in lower ICW

Discussion

The current study was performed among Egyptian children and adolescents, to analyze the dimensions and form of the dental arches of Egyptian children with normal occlusion, through different dentition stages, to be used in further diagnosis and treatment planning of Egyptian children.

The study sample included dental casts for children their age ranged from 4 to 14 years, to be able to perform the required measurements upon primary dentition, mixed dentition as well as permanent dentition, to represent different stages of growth and development.

Casts with missing, rotated or malformed teeth were excluded from the current study as well as casts with air bubbles especially at the area of the cusp tips, as these factors would interfere with placement of the reference points that were used for performing arch dimensions (Othman et al. 2012).
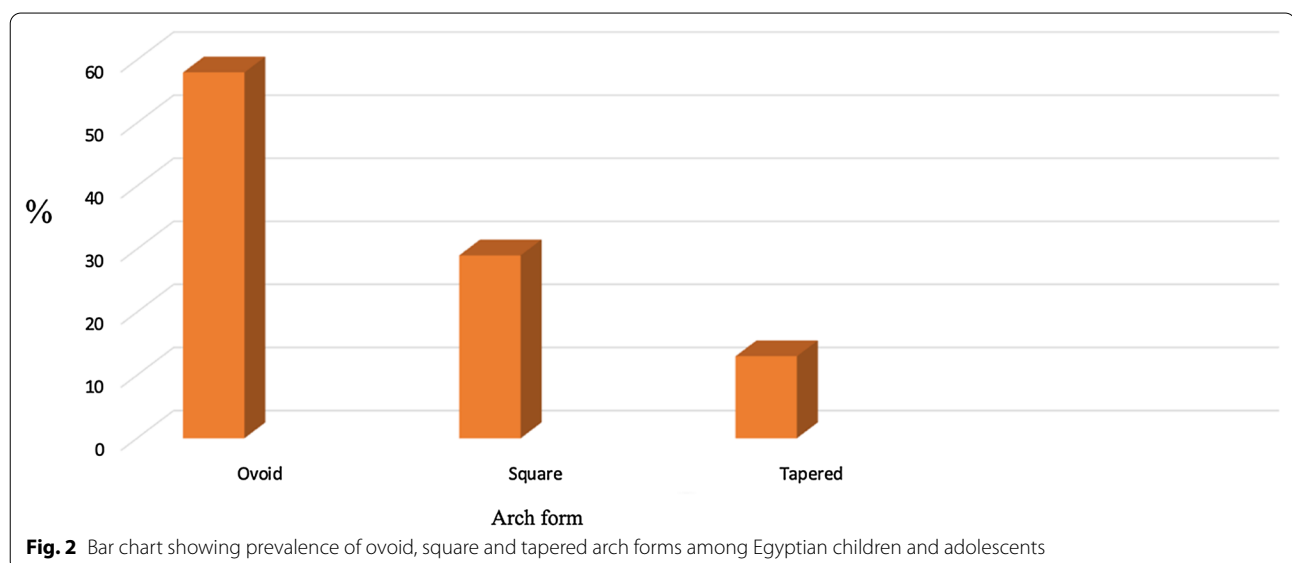
Scant studies were carried out to determine the average dental arch dimensions and arch forms for Egyptian children with normal occlusion among different cities in Egypt, like Giza (El-Yazeed and Abou-Zeid 2013), Mansoura (Shamaa 2019), Fayoum (Salam et al. 2022), and another one was performed in Upper Egypt (Labib et al. 2003).

On the other hand, few studies compared between Egyptian population and other populations, e.g., Bayoumi et al. (2011) compared between Egyptian and North American white populations in arch form, while Younis (1984) studied the differences in arch dimensions between Egyptian and Saudi populations.

Results of the current study demonstrated that intercanine width showed slight increase during transition from primary to mixed dentition in the upper and lower arches, while marked increase was noticed in the upper and lower ICW (from 30.88 to 35.18 and from 24.98 to 28.01, respectively) and IMW (from 43.61 to 46.95 and from 39.20 to 42.74, respectively) during transition from mixed to permanent dentition. These findings agreed with Hassanali and Odhiambo (2000), Sangwan et al. (2011) and Ribeiro et al. (2012).

This can be explained by the eruption of the permanent canines and second permanent molar, so that eruption of permanent teeth is accompanied by change in the arch size, dimensions of the arch and direction of growth of the alveolar process as well as alignment of teeth (Ghamidi et al. 2020).

At the same time, these results partially contradict with Louly (2011) who studied the changes in the arch

Fig. 2 Bar chart showing prevalence of ovoid, square and tapered arch forms among Egyptian children and adolescents

dimensions among Brazilian children. Results of the Brazilian population showed decrease in intercanine width in the lower arch during transition from mixed to permanent dentition, and this contradiction can be due to ethnic and genetic differences which affect the pattern of growth and shape of the arch.

Results revealed statistically significant difference in the lower intercanine width between males and females ($p = 0.044$) through different dentitions; these results agreed with Salam et al. (2022) who used the Cone Beam Computed Tomography (CBCT) for assessment of the arch dimensions; this agreement in the results can be because both studies were performed among Egyptian population, so there was no racial or genetic differences among the study samples.

In the current study, the TAL increased during transition from mixed to permanent dentition in the upper and lower arches (from 32.86 to 35.74 and from 29.19 to 30.42, respectively), and it was noticed that the average increase in the TAL during transition between dentitions was more in upper arch than in the lower. These results were in agreement with Bishara et al. (1998), who found that the increase in the maxillary arch length was much more than the increase that occurred in the mandibular arch length, during transition from mixed to permanent dentition and that was justified by the author by continuous increase in the maxillary arch length till the age of 13 years while the lower arch length didn't increase after the age of 8 years.

Results of the current study were in partial agreement with Louly et al. (2011) who found that, among Brazilian children, the maxillary total arch length increased from the age of 9 years to the age of 12 years, and this increase in the TAL was justified by the eruption of the maxillary permanent canines. However, results of the same study recorded a small non-significant decrease in mandibular TAL from the age of 9 years to the age of 12 years, which is contradicting with results of the current study, which found non-significant increase in the lower TAL during transition from mixed to permanent dentition, and the contradiction in this point can be due to differences in the reference points used to measure the arch dimensions and different age group of the patients included in the two studies.

Arch perimeter increased in both maxillary and mandibular arches during transition from primary to mixed and then to permanent dentition, due to growth and development of the maxillary and mandibular arches and alveolar process during transition between dentitions, as well as eruption of the maxillary first permanent molars in a distobuccal direction (Ghamidi et al. 2020).

Understanding the changes that occur in the dental arches during transition from primary to mixed and ending with the permanent dentition is quite important for the pedodontists and orthodontists, to be able to select the suitable treatment plan for the patient that maintain stable occlusion and proper alignment of teeth. At the same time, the clinician should be aware of the changes that occur in the arch length, width and perimeter to be able to explain to the parents of the child the most suitable treatment plan and the possible changes that can occur during treatment due to growth and development of the dental arches (Kareem F. 2011).

It is clear that differences in racial origins, as well as differences in environmental factors, can explain the statistically significant differences in the dimensions of the dental arches in children from different continents with distinct genetics and diverse living conditions (Othman et al. 2012; Barman et al. 2021).

Regarding the arch form, it was found that anterior arch length together with intercanine width (ICW) play an important role in determining the arch form, as these measurements shape the anterior part of the arch, thus affect the form of the arch (Bayome et al. 2011; Aljayousi et al. 2021).

The ovoid arch form was found to be the most predominant among Egyptian Children and adolescence, and these results were in accordance with Mageet et al. (2018), who found that, among the Sudanese population, the ovoid form of the arch was the most common. While these results contradict with Labib et al. (2003), who found that the most common arch forms for the upper arch were the wide and pointed forms while in the lower arch the wide form was predominating, this can be explained by using different classification for the arch forms which differ from the one used in the current study.

At the same time, results of the current study contradict with Kook et al. (2004), who found that the square arch form was more common among the Korean population while the tapered arch form was predominant among the North American white population, and these differences confirm the concept that arch measurements and form are affected by the race and variable environmental factors (Prasad et al. 2013).

Conclusions
Dental arch measurements of Egyptian children and adolescents can be used as a guide for treatment planning of Egyptian children and can be used in further studies for comparison of the arch dimensions of the Egyptian children with other populations. It was found that during transition from primary to mixed and then to permanent

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dentition, the arch measurements (intercanine, intermolar, arch length and arch perimeter) increased in both maxillary and mandibular arches and there was non-significant difference in these measurements between males and females, except in the lower inter canine width. Regarding the arch form, the ovoid arch form was the most common among the Egyptian population followed by the square while the tapered arch form was the least common one.

Abbreviations
TAL: Total arch length; AAL: Anterior arch length; PAL: Posterior arch length; ICW: Intercanine width; AP: Arch perimeter.

Declaration

Ethics approval and consent to participate
The study was approved by the Medical Research Ethics committee of the National Research Centre of Egypt and the approval number is 16–343. Parents of all the patients who participated in the current study, signed an informed consent that they accept participating in the study and publication of the results.

Consent for publication
All the participant in the current study signed a consent that they accept publication of the results of the study.

Competing interests
The authors declare no competing interests.

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