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Research article

An efficacious horizontal angulation separated radiographically superimposed canals in upper premolars with different root morphologies

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ABSTRACT

Objectives: To determine the effect of various horizontal beam angulations on radiographically separating superimposed canals in upper premolars with different external root morphologies.

Materials and methods: The independent variables were 1) three different external root morphologies of upper premolars ($n = 30$); one-root (A), fused-root (B) and two-root (C), 2) thirteen angulations (0° and mesial (Ms) and distal (Ds) shifts of 15, 20, 25, 30, 35, and 40°), and 3) the superimposed canal at the apex (apx) and 5-mm from the apex (5apx). The dependent variables were the percentage of radiographs demonstrating canal separation. The separated canal distances were analysed using analysis of variance (ANOVA) and Tukey HSD.

Results: Separation distances at apx and 5apx on one-root, fused-root and two-root premolar radiographs increased as the angulation increased. Ms angulations generated a higher separation distance (SepDist) in mm compared with the Ds angulations. Significantly different separation distances were observed from various horizontal shift angulations ($p < 0.05$). Percentage of canal separation from 0° was achieved differently in different morphology of upper premolars (14–80%) at apx and 10–40% at 5apx. The 20–40Ms/Ds and 25Ds/30–40Ms/Ds resulted in 100% of radiographs with canal separation for two-root and fused-root premolars, respectively, at apx and 5apx. Only the 35/40Ms resulted in 100% of radiographs with separation at apx in one-root teeth.

Conclusion: The ideal horizontal angulation which revealed the superimposed canal at the apx/5apx for one-root, fused-root, and two-root teeth are 35M/35M, 20D/20M, and 15M/20M, respectively.

Significance: The 25Ms was the optimal angulation which strongly recommended with the highest probability of separation and acceptable image quality in endodontic and prosthodontic treatment for unknown morphologies evaluated.

1. Introduction

Understanding tooth anatomy and root canal morphology are essential for successful root canal treatment [1] and subsequent tooth restoration [2]. Treatment failure commonly results from root canal morphology variation, and two-dimensional radiographs do not always reveal superimposed untreated canals and the amount of 4–5 mm apical gutta-percha seal.

The root morphology of upper first premolars varies, with three-root (0–6%), one-root (10–49.4%) and two-root (50.6–85%) teeth observed. Two-root premolars present as fused-root (13.5–33%) and distinct root or two-root teeth (18.5–57%) [3, 4, 5, 6, 7]. Predominant root morphology also demonstrates ethnic variability towards one root [8, 9] and two roots [4, 5, 7, 9, 10, 11, 12]. In contrast, upper second premolars most commonly have one root (55.3–90.3%), with 9.7%–44.2% found to have two roots. The prevalence of three roots in these teeth is extremely low (0.3–0.46%) [1, 13, 14].

Previously, superimposed root canals on radiographs can be separated by changing angle from either mesial or distal horizontal direction using buccal object rule [15, 16, 17]. Irrespective of root morphology, mesial horizontal angulations of 20° [6,18], 25° [19], 30° [20] and 40° [18] separated superimposed canal in upper premolars. The authors hypothesized that upper premolars with different root forms might require specific mesial or distal horizontal angled radiographs to separate superimposed canals. Then, the objective was to determine the effect of various horizontal beam angulations on radiographically separating superimposed canals in upper premolars with different external root morphologies at the apex and 5-mm from the apex.

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2. Materials and methods

2.1. Samples

The study protocol was approved by the Institutional Ethics Committee at Rangsit University, Pathumthani, Bangkok (#RSEC 38/2558). Purposive sampling was used to generate 3 groups (n = 10) of permanent extracted upper premolars based on root morphologies. Power analyses of one-root, fused-root and two-root premolars were 0.89, 0.99 and 0.99 respectively. The selected upper premolars should have two canals with completed root formation. The remaining morphology could identify their correct position. Teeth with root canal curvature, and dilacerations were excluded.

2.2. Procedures

The samples were cleaned and disinfected by storing in 10% formalin. Access openings were achieved ideal straight-line access and conservative tooth structure removal. The samples were placed in a 2.5% sodium hypochlorite solution to dissolve the organic tissue from the root canal system.

An ISO 08/.02 K-file was inserted into the canal to negotiate the shape and size of the apical-third of the root canal. The coronal root canal preparation was performed using the crown-down technique with #2, 3, and 4 Gates-Glidden drills (DENTSPLY, Maillefer, Tulsa, Oklahoma) to decrease the coronal contact and increase tactile sense apically. To verify canal location, a 15-K file and a 15-H file with a rubber stopper were inserted in the buccal and lingual canal and advanced until the file tip appeared at the foramen. The stopper was set at the occlusal reference point.

2.3. Radiographic examinations

A PLK jig (petty patent No. 1703001943) was used in combination with a Rinn-Endo-Ray film holder (DENTSPLY/Rinn Corporation, Elgin, IL, USA) to determine the 0^o vertical angulation and horizontal angulations at 5^o intervals of 15, 20, 25, 30, 35, and 40^o from the mesial or distal direction. The angles were also determined using a rotating stand, semicircular angle ruler, and indicating pin to confirm the mesial shift (Ms) and distal shift (Ds) angulations (Figure 1A-B). All images were exposed using conventional X-ray equipment at 65 kV, 7 mA (Progeny Preva DC Intraoral X-ray system) with an exposure time of 0.1 s. DenOptix imaging plates size 2 (DENTSPLY/Gendex, Chicago. IL, USA) were used to evaluate the number of root canals. A total of 13 radiographs were made of each tooth with respect angulation of each specimen. Measurements will be performed on the monitor screen using digital ruler from Vixwin Platinum version 1.2 (Gendex dental systems, Des Plaines, Ill). Separation distance between 15-K file and a 15-H file in superimposed canal were recorded.

2.4. Statistical analysis

The intra-observer reliability was calculated using the paired-t test followed by an intraclass correlation coefficient (ICC). Power analysis was performed to determine the optimal sample size using G*Power software v.3.0.10 [21]. The data was collected and analysed using IBM SPSS Statistic for Windows, Version 22 (IBM Corp., SPSS Statistics for Windows, Armonk, NY, USA). Descriptive statistics were analysed for each variables. One-way ANOVA with post-hoc Tukey HSD Test was conducted to compare the significant effect of varying the horizontal shift angulation to the separation distances ($P < 0.05$). The percentage of separation from each angulation were calculated based on the distance which could also be separated in the radiograph when using master apical file (MAF) 30/05. Then, this value was calculated based on the principle of centred preparations which could cause by rotary cutting Ni–Ti instruments [22]. The cut-off point separation distances at 0.15 from apx and 0.3 from 5apx were retrieved from Master apical file (MAF) size 30/.05.

3. Results

There were strong correlations of intra-observer variability in evaluating the 0, 15, 20, 25, 30, 35 and 40^o mesial and distal shifted angulations ($p > 0.05$; ICC = 0.998; 95% CI, 0.995–0.999).

3.1. At the apex (apx)

The premolar radiographs demonstrated that the Ms angulations generated a higher separation distance (SepDist) in mm at apx compared with the Ds angulations (mean 2.21; SD, +1.70 and mean 1.25; SD, +1.10, respectively). The mean SepDist between two-root and fused-root premolars were significantly different ($p < 0.05$). However, varying the angulation did not significantly affect canal separation at apx of one-root teeth ($F (12, 78) = 1.70$, $p = 0.083$). Post hoc comparison using the Tukey HSD test indicated that the mean SepDist on the 0^o two-root premolar radiographs (0.75 ± 0.56) was significantly lower compared with the 25/30/35/40Ms and 35/40Ds radiographs. Moreover, the mean SepDist on the 0^o angled fused-root teeth radiographs (0.44 ± 0.63) was

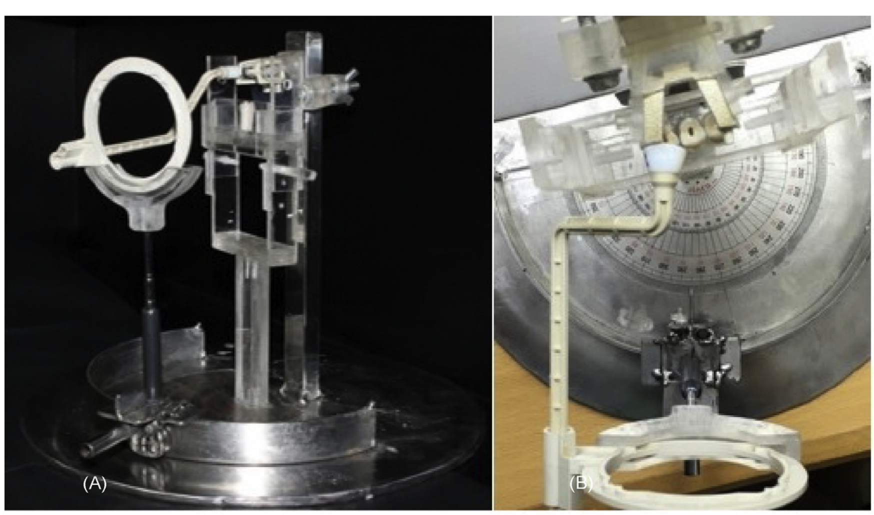


Figure 1. Experimental arrangement. (A) The radiograph is taken with tooth placed on the central carrier stand with angle measurement ruler; this enables precise variations in cone angulation. (B) Image of a 15^o mesial shift angulation set up, where the PLK Jig (petty patent No. 1703001943) is coupled with the Endoray (right).

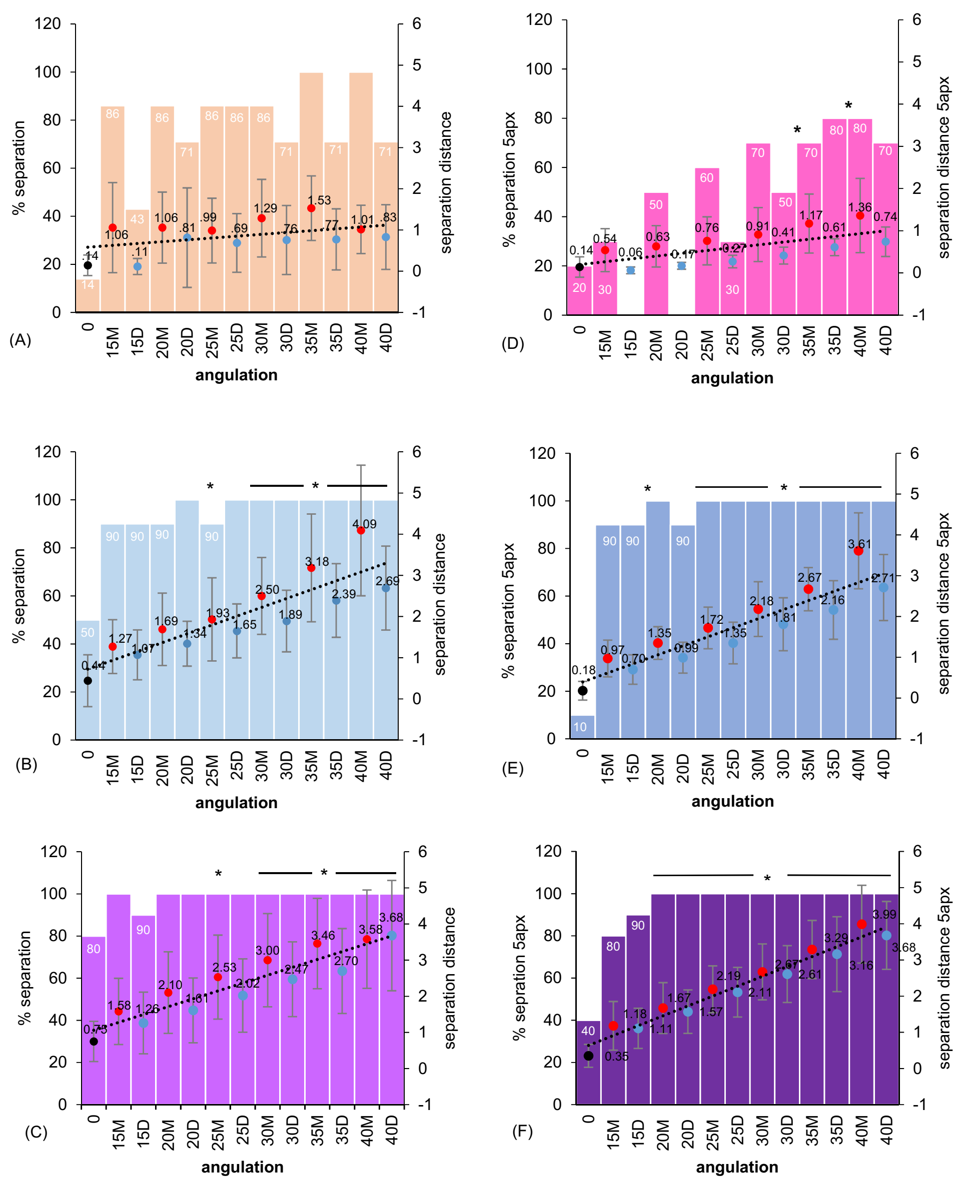
significantly lower compared with the 25/30/35/40Ms and 30/35/40Ds radiographs.

Between the three premolar types, the percentage of radiographs with canal separation at 0° increased from one-root (14%), fused-root (50%), and two-root premolars (80%) (Figure 2A, B, C). In one-root teeth, 100% of the 35Ms (1.53 ± 0.78) and 40Ms (1.01 ± 0.59) radiographs demonstrated canal separation. Canal separation was found in 86% of the 15Ms (1.06 ± 1.09), 20Ms (1.06 ± 0.86), 25Ms (0.99 ± 0.79), 25Ds (0.69 ± 0.71), and 30Ms (1.29 ± 0.94) radiographs. We observed canal separation on 100% of the 20/25Ds and 30–40 Ms/Ds radiographs of fused-root teeth. Ninety percent of the 15Ms (1.27 ± 0.65), 15Ds (1.07 ± 0.61), 20Ms (1.69 ± 0.88), and 25Ms (1.93 ± 1.01) radiographs demonstrated canal separation (Figure 2C). However, 100% of the 15–40Ms/Ds two-rooted premolar radiographs showed separate canals, except for the 15Ds radiographs (Figure 2C). However, when comparing the SeptDist using angulation less than 30Ms angulation, the 25Ms was strongly recommended.

3.2. 5 mm from the apex (5apx)

At 5apx, the mean SepDist generated by the Ms angulations were also higher compared with the DS angulations (2.08 ± 1.19 and 1.70 ± 1.10, respectively). There was a significant effect from the horizontal shifted angulations on the canal SepDist in the different root premolars 5apx (F (12,338) = 20.356, p = 0.000). At 0°, canal separation was achieved in 20%, 10%, and 40% of the one-root, fused-root, and two-root premolar radiographs, respectively (Figure 2D, E, F).

For one-root teeth, the mean SepDist on the 0° angled radiographs (0.14 ± 0.24) was significantly lower compared with the 35/40Ms radiographs ($p < 0.05$). No angulation generated 100% of radiographs with canal separation. However, separation was present on 80% of the 35Ds (0.61 ± 0.20) and 40Ms (1.36 ± 0.88) radiographs (Figure 2D). Although 70% of the 30/35Ms, and 40Ds radiographs showed separated canals, image distortion and overlapping with the adjacent teeth were observed. The highest percentage of radiographs (60%) (0.76 ± 0.57)



* Indicates significantly different separation difference from 0° angulation (P<0.05).

Figure 2. Combination graphs with co x-axis representing the mean ± SD separate distance from the mesial direction (red dot) and the distal direction (blue dot) in comparison with the separation rate achieved from different horizontal angulation at the apx/5apx of one-root (A/D),fused-root (B/E) and two-root (C/F) upper premolars.

demonstrating separation with the best quality image was achieved by 25Ms angulation.

On the fused-root tooth radiographs, the mean SepDist on the 0^o angled radiographs (0.18 $\pm$ 0.23) was significantly lower compared with the 20Ms, and 25–40Ms/Ds radiographs ($p < 0.05$), 100% of which demonstrated superimposed canal separation. We found that 90% of the15Ms/Ds and 20Ds radiographs presented separated canals (Figure 2E).

For two-root teeth, the mean SepDist on the 0^o angled radiographs (0.35 $\pm$ 0.32) was significantly lower compared with the 20–40Ms/Ds radiographs. One-hundred percent of the 20–40Ms/Ds radiographs showed separated canals. We observed that 80% and 90% of the 15Ms and 15Ds radiographs, respectively, had separated canals (Figure 2F).

The results (shown in Figure 2A-F) suggested that the ideal horizontal angulation which revealed the superimposed canal at the apx/5apx for one-root, fused-root, and two-root teeth were 35M/35M, 20D/20M, and 15M/20M, respectively. However, when comparing the SeptDist using angulation less than 30Ms angulation, the 25Ms was strongly recommended (see Figure 3). Even though, there was no significant different of mean separation in one root at both apex and 5 mm from apex, but the highest percent separation observed from 25M at 5apx. On the other hand, there were significant higher mean Septdis with high percentage of separating distance observed in 25M in both apex and 5mm from apex of both fused root 1.93 $\pm$ 1.01 (90%), 1.72 $\pm$ 0.51 (100%) and two roots 2.53 $\pm$ 1.16 (100%), 2.19 $\pm$ 0.65 (100%).

4. Discussion

Pre-operative radiographies are important in endodontic diagnosis and treatment planning. Straight facial radiographs (0^o) provide a mesio-distal view, however, properly angled radiographs provide a facial-lingual view [23] with a higher diagnostic accuracy in determining the number of roots and canals. At 0^o, digital and conventional radiographs have a low diagnostic accuracy, demonstrating the correct root canal anatomy in 31.1% and 35.6% of the radiographs, respectively [20]. Our results demonstrated canal separation from 14-80% depending on the root morphology.

The Endoray film-holding instrument aided in performing the paralleling. However, root canal separation using the shifted tube technique was difficult to achieve the repeated shifted angulation and correct point of entry of x-ray. We solved this problem by using the PLK jig with a carrier stand that allowed the proper horizontal angulation without disturbing the vertical angulation. Because the effect of vertical angulation [18, 19] is unresolved, we only determined the best horizontal shift angulation for separating superimposed canals in upper premolars.

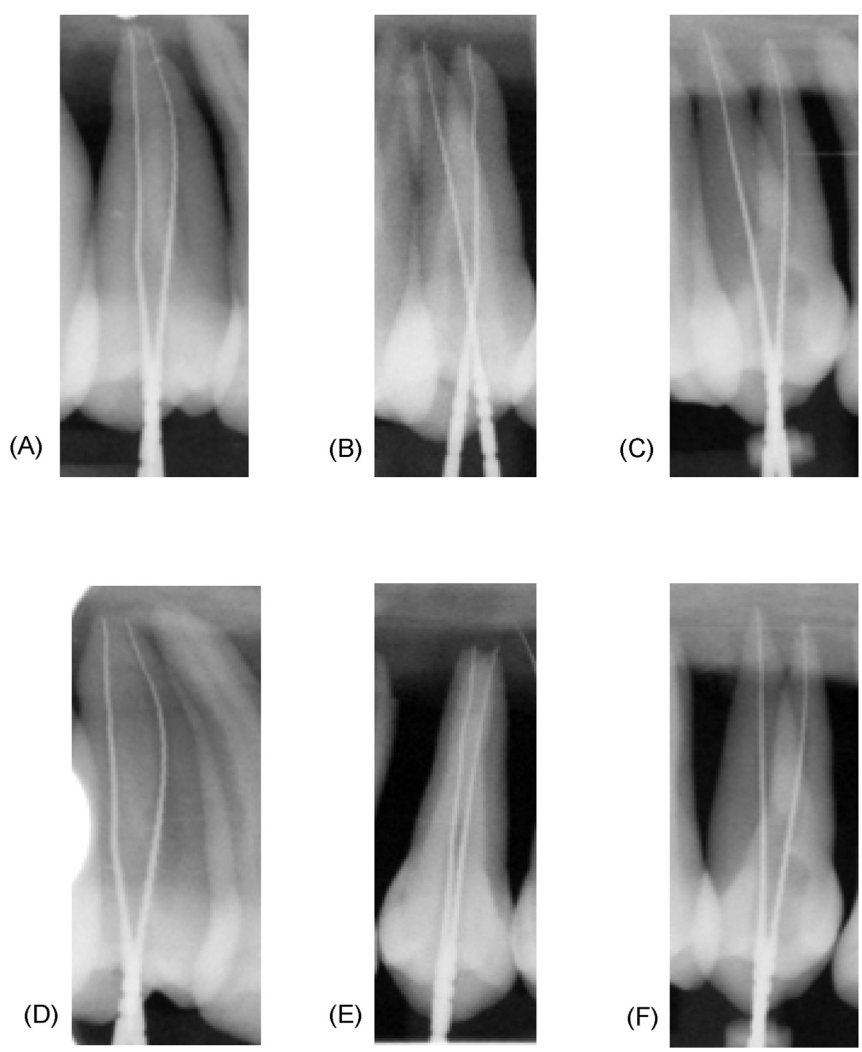


Figure 3. Radiographs taken using the 25 M horizontal angulation of the three different external root morphologies; one-root (A), fused-root (B) and two-root (C) upper premolars. The lowest effective angulation that achieved canal separation in 100% of the radiographs at apx; 35M for one-root (D), 20D for fused-root (E) and 15M for two-root (F) upper premolars.

Previous studies on varying the horizontal angulation found that 20° [18,24], 30° [20], and 40° [18] angled radiographs demonstrated the actual number of canals compared with 0° radiographs. In our study, the best Ms and Ds angulation was determined by stepwise changes of 5° from 15–40°. If the upper premolar root morphology is known, then the optimum horizontal angulation for separating superimposed canals at the apx/5apx for one-root, fused-root, and two-root teeth are 35M/35M, 20D/20M, and 15M/20M, respectively, which all generated SepDist >1 mm that can be visually discerned on both digital and conventional images without magnification.

A limitation of the present study is that did not account for differences in oral anatomy which could limit the anterior positioning of the film and affect the region of interest. Thus, the recommended use of a 20Ds angulation for fused-root premolars may not be applicable for patients with a shallow anterior palatal vault. Therefore, the use of a 30M shift is suggested. Besides, the upper second premolars which have highest prevalence of superimposed canal in one-root and two-root forms [1, 13, 14] could be at best for both apx/5apx at 35 M/35M and 15M/20M respectively. However, they might be effect due to the different position in the dentition. However, further studies should be performed *in vivo* to determine the effects of different oral anatomy types on radiograph angulation.

The effect of vertical angulation on canal separation has been inconsistent between *in vitro* [18] and *in vivo* [19] studies evaluating 20M and 25M horizontal angulation. The recommended use of 25M angulation without vertical angulation modification in previous studies corresponds with those of the present study.

The information regarding root canal anatomy that is evident radiographically is valuable. Even though using Cone-beam computed tomography (CBCT) which provides three dimensional data have been rapidly increasing used in endodontic treatment, it is still not overcome the beneficial of shifted tube technique by using periapical films during root canal treatment and post preparation procedure. If repeated angulation could be performed, the similar views could ease the canal path navigation and also value for comparing pre and post treatment with less cost and radiation dose than CBCT.

Knowledge of the optimum radiograph angulation for premolars with distinct root morphology should improve the radiographs' diagnostic quality, while reducing the radiation exposure to the patient as low as reasonably achievable.

The best horizontal angulation which revealed the highest opportunity of separation and achieved more than 1mm SepDist of superimposed canal at the apx/5apx for one-root, fused-root, and two-root teeth were 35M/35M, 20D/20M, and 15M/20M, respectively. Alternatively, the 25Ms generated the suitable separated superimposed canal in radiograph for determining the appropriate working length and post space determination in indefinite morphology treated tooth.

Declarations

Author contribution statement

Piyanuch Karnasuta: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Watcharin Chongkonsatit: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Chavalit Chavanaves: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

La-ongthong Vajrabhaya: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Nonthana Panrenu: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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