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Comparative Assessment of Canine Retraction Rate using Differential Height Soldered Power Arm in Extraction Cases– A Split Mouth Study

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Abstract: Objective: This investigation compared the efficacy of variable-height soldered power arms in canine retraction using a split-mouth design. **Background**: Orthodontic treatment for protruding teeth often involves premolar extractions followed by canine retraction using friction mechanics using a power arm. This study compared the effectiveness of different power arm heights forcanine retraction. **Methods:** Twenty patients (16-25 years) requiring premolar extractions and canine retraction were randomised into two groups. Group 1 received a 9mm power armandGroup 2 received a 6mm power arm on the designated study side, with both groups receiving a standard 3mm power armon the control side. Canine retraction, anchorage loss, and angulation were evaluated at 3 and 6 months using radiographic and model analysis. **Results:** The 9mm power arm achieved significantly greater canine retraction compared to the 6mm power arm at both three and six months. The 9mm power arm also resulted in more controlled bodily movement of the canine, whereas the 6mm power arm exhibited uncontrolled tipping. **Conclusion:** The 9mm power arm facilitated efficient and controlled bodily canine retraction due to its proximity to the tooth's center of resistance. This finding suggests that a 9mm power arm may be preferable for efficient space closure and achieving bodily tooth movement in two-step retraction or isolated canine retraction scenarios, compared to the conventionally used 6mm and 3mm power arms.

Keywords: Canine retraction, Premolar extraction, Friction mechanics, Variable height power arm ,Ni-Ti coil spring.

Introduction:

Orthodontic correction of protrusion in patients with adequate bone support often involves premolar extractions followed by anterior retraction. This retraction can be achieved via frictionless mechanics (loops) or frictional mechanics (elastic chains, Ni Ti coil springs, and e-ties). In the realm of frictional mechanics, the focus of force application is directed towards the anterior area, particularly targeting power arm positioned between lateral and canine brackets during en-masse retraction, and specifically towards the canine power arm in cases of isolated canine retraction. Two primary retraction approaches exist [1, 2]: separate canine and incisors retraction to minimize posterior anchorage stress, and en-masse retraction focusing on tooth movement patterns. Modern edgewise appliances offer various retraction methods.

Stainless steel ligatures and elastic chains have limitations like rapid force dissipation and degradation. Closed-coil nickel-titanium (Ni-Ti) springs are preferred because of their extended activation range and force delivery that is consistent[3].

When employing sliding mechanics for retraction, the power arm exerts force towards the centre of resistance (CR) of the six anterior teeth, situated 5mm distal and 9-12mm apical to the centre of the lateral bracket [4]. In instances of two-step retraction, the force is aimed at the CR of the canine, located beneath the alveolar crest roughly by 8.2mm, equivalent to about two-fifths of the root length [5]. To modify the point of force application concerning the CR, power arms of different heights (3mm, 6mm, 9mm) can be attached to the existing 3mm canine power arms through soldering. A split-mouth design was utilized in this research to comparatively assess the efficacy of these various power arm heights in the process of canine retraction.

Aim and objectives:

The study aimed at comparing the effectiveness and retraction time achieved through differential height soldered power arms for canine retraction. A split-mouth design with a 6-month follow-up was employed. The following parameters were evaluated:

- Amount of canine retraction at 6 months using study models.
- Anchorage loss assessed using study models.
- Bodily movement of the canine.

Materials and methods:

Following the acquisition of ethical approval from the Institutional Ethical Clearance Committee, this prospective in vivo investigation was undertaken within the Department of Orthodontics and Dentofacial Orthopaedics at our institution. Twenty patients aged 16-25 undergoing first premolar extractions with minimal crowding, no tooth pathology, and at least 4mm distal canine space were selected. All participants had completed the leveling and alignment phase and exhibited low/average skeletal angle and anchorage. Patients with medical/periodontal issues, severe crowding, high angle/anchorage, or missing molars were excluded. The study employed a split-mouth design with two different soldered power arm lengths (3mm and 6mm) attached to the existing canine bracket power arms which measures

3mm . After obtaining informed consent from both patients and patients's parents who were under 18 years of age, the procedures were explained in detail.

Two soldered power arm lengths (3mm and 6mm) were fabricated and attached to standard upper and lower canine brackets with existing 3mm power arms. These arms were randomly assigned to opposing sides for each patient. Ten patients received a 9mm power arm, while the other ten received a 6mm power arm on their designated side. All four canines were bonded according to the study criteria.Nickel-titanium closed-coil springs were employed to aid in retraction bilaterally. The retraction phase involved the use of a preadjusted 0.022 MBT (ORMCO) edgewise appliance featuring upper double and lower single buccal tubes, with engagement of a 0.017" x 0.025" stainless steel wire. Standardizedcalibrations were obtained using lateral cephalograms, OPGs, intraoral photographs, and study models throughout the treatment course. Canine angulation, retraction amount, anchorage loss, and bodily movement were evaluated to assess the effectiveness of the differential power arm heights.

Brass wires of 3mm and 6mm lengths were soldered to existing 3mm canine bracket power arms. For stabilization during soldering, the brackets were secured in plaster with only the power arm head exposed. Petroleum jelly prevented investment material from entrapping the bracket mesh. Flux was applied to the contact points, and silver solder melted with a torch to join the brass wires to the existing power arms. Neo-Sentalloy (JJ Orthodontics) 9mm retraction springs with 150g force were employed [6].

Cephalometric evaluation was performed using lateral cephalograms and OPGs with reference markers at baseline, 3 months, and 6 months. Standardized intraoral photographs were obtained at each time point. Additionally, study models were collected monthly during the 6-month retraction period. Custom lead wire reference markers were fabricated in "L"(left) and "R"(right) shapes to identify canines during retraction measurement [7]. These markers were temporarily ligated to the left and right canines before pre-operative radiographs. The same markers were re-attached before post-operative radiographs at 3 and 6 months.

Canine retraction and anchorage loss were assessed by comparing pre-retraction and post-retraction study models [8].Canine and molar displacement was quantified using a custom-fabricated acrylic palatal reference plate secured to the maxillary dental cast. Constructed at baseline (T0), this reference plate incorporated calibrated wires extending to the canine cusp apex and the central fossa of the first molar. The plug was subsequently assessed on models obtained every

4 weeks following canine retraction completion. Retraction rate (mm/interval) was calculated as distance traveled divided by time for space closure. Intervals were defined as 4-week periods with patient visits at each interval until retraction completion. Measurements used direct comparison of pre-retraction, 3-month, and 6-month stone casts. The displacement of the canine cusp was meticulously quantified using a calibrated caliper. Measurements were obtained between the most apical aspect of the canine cusp and a pre-positioned reference wire at designated intervals. Total retraction was obtained by subtracting the initial measurement from the 3-month and 6-month interval values. Measurements were taken and the mean value was used.

Mesial movement of the first molar, signifying anchorage loss, was meticulously evaluated on dental casts utilizing a digital vernier caliper. This approach eliminated the requirement for ionizing radiation exposure. This involved measuring the distance from the molar's central fossa to the pre-placed reference wire tip, allowing visualization of molar protraction.

Pre- and post-retraction orthopantomograms (OPGs) were employed to assess canine angulation relative to the infraorbital plane. The inclination of the canine teeth, defined as the angle formed between the infraorbital plane and the long axis of each canine, was bilaterally quantified on both sides, with pre-treatment measurements compared to their post-treatment counterparts[9].

Results:

The effectiveness of the intervention was assessed by comparing pre-retraction and post-retraction radiographs and dental cast analyses.

Determination of Amount of Retraction

Canine retraction varied by power arm length: The 6mm arm achieved 1.69mm of retraction at 3 months and 2.42mm at 6 months, and the 3mm arm when compared to 6mm arm achieved 2.68mm at 3 months and 3.86mm at 6 months respectively. The 9mm arm achieved a mean of 4.02mm at 3 months and 5.68mm at 6 months in comparison to 3mm which achieved 3.00mm at 3 months and 4.01mm at 6 months respectively.

Determination of Anchorage Loss

Anchorage loss increased over time for both power arm lengths. The 9mm arm exhibited an average loss of 0.66mm at 3 months and 0.96mm at 6 months (Table 3), while the 6mm arm showed an average loss of 0.58mm at 3 months and 0.89mm at 6 months.

Angular changes in canine pre and post-retraction

Canine angulation relative to the infraorbital plane, assessed pre-retraction and at 3- and 6-months post-retraction, revealed bodily movement with the 9mm power arm, while the 6mm arm exhibited uncontrolled tipping.

Data from radiographs and dental casts were recorded in Microsoft Excel and analyzed utilizing IBM SPSS (version 22.0). Descriptive statistics (standard deviation,mean, minimum, maximum) were calculated. Paired t-tests assessed the anchorage loss,rate of tooth movement and angulation changes. Statistically significant increases in canine retraction were observed between 3 and 6 months for both the 3mm (mean difference: 1.01 ± 0.19; $p < 0.001$) and 9mm power arms (mean difference: 1.66 ± 0.10; $p < 0.001$) (Table 1,Graph 1). The 9mm arm achieved significantly greater retraction compared to the 3mm arm .Similarly, changes that were statistically significant were observed in angulation of canine between 3 and 6 months for both the 3mm (mean difference: 0.90 ± 0.62; $p < 0.001$) and 9mm power arms (mean difference: 1.08 ± 0.39; $p < 0.001$) (Tables 2 ,Graph 1,2). Notably, the 9mm arm exhibited greater anchorage loss compared to the 3mm arm (Table 2,Graph 2).

Furthermore, statistically significant increases in canine retraction were observed between 3 and 6 months for 3mm and 6mm power arm lengths (3mm: 1.18 ± 0.21, 6mm: 0.73 ± 0.14; $p < 0.001$ for both) (Table 2). The 3mm power arm also demonstrated significant changes in canine angulation (mean difference: 0.84 ± 0.16; $p < 0.001$) (Tables 1,2).No statistically significant variations in anchorage loss were identified between the 3mm and 6mm power arms at either 3 or 6 months. Conversely, canine angulation showed significant differences between all power arm comparisons (Tables 1,2,). The 3mm power arm resulted in greater tipping compared to both the 9mm and 6mm arms, as evidenced by higher mean angulation values at both time points.

Table 1-Comparison of canine retraction rate, Anchorage loss and Angular changes between 6mm and 3mm power arm after 3 and 6 months

		Paired Differences				**P value**
		Mean	**Std. Deviation**	**95% Confidence Interval of the Difference**		
				Lower	**Upper**	
Pair 1	**RR3mR3 - RR6mR3**	1.183	0.21365	1.33583	1.03017	<0.001 *
Pair 2	**RR3mR6 - RR6mR6**	0.728	0.14861	0.83431	0.62169	<0.001 *
Pair 3	**AL3mR3 - AL6mR6**	0.02	0.07888	-0.07643	0.03643	0.443
Pair 4	**AL3mR3 - AL6mR6**	0.02	0.07888	-0.07643	0.03643	0.443
Pair 5	**AnCh3mR3-AnCh6mR3**	0.84	0.1647	0.9578	0.7222	<0.001 *
Pair 6	**AnCh3mR6 - AnCh6mR6**	0.92	0.1135	1.0012	0.8388	<0.001 *
*** = Significant p value**						
RR - Retraction rate; AL - Anchorage loss; AnCh - Angular Changes; 3m - 3 months; 6m - 6months; R3 - 3mm power arm; R6 - 6mm power arm						

Fig1-Comparison of canine retraction rate, Anchorage loss and Angular changes between 6mm and 3mm power armafter 3 and 6 months

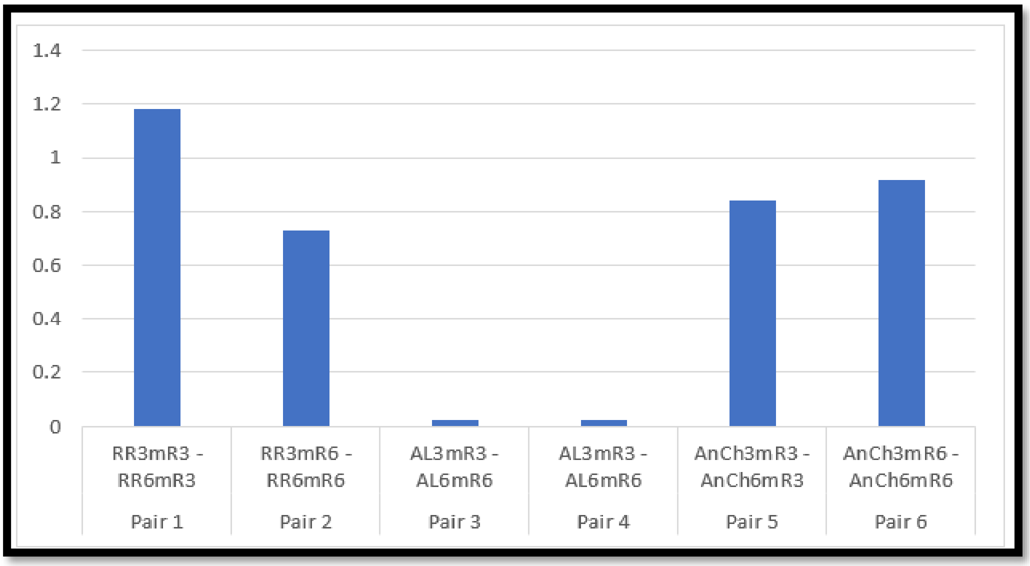
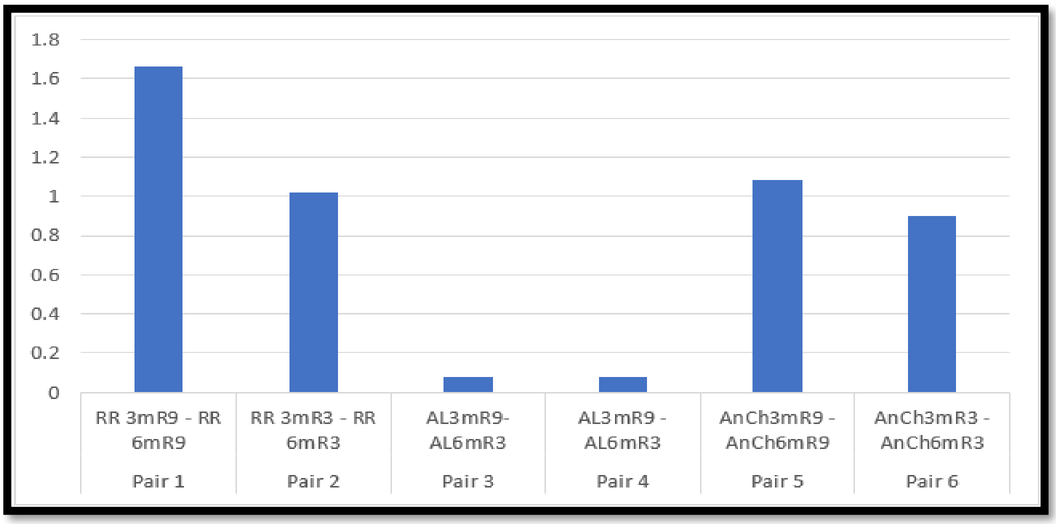


Table2- Comparison of canine retraction rate, Anchorage loss and Angular changes between 9mm and 3mm power arm after 3 and 6 months

		Paired Differences				P value
		Mean	Std. Deviation	95% Confidence Interval of the Difference		
				Lower	Upper	
Pair 1	**RR 3mR9 - RR 6mR9**	1.661	0.10246	1.7343	1.5877	**<0.001**
Pair 2	**RR 3mR3 - RR 6mR3**	1.017	0.19625	1.15739	0.87661	**<0.001**
Pair 3	**AL3mR9-AL6mR3**	0.08	0.0632	0.0348	0.1252	**0.003**
Pair 4	**AL3mR9 - AL6mR3**	0.08	0.0632	0.0348	0.1252	**0.003**
Pair 5	**AnCh3mR9-AnCh6mR9**	1.08	0.38528	1.35562	0.80438	**<0.001**
Pair 6	**AnCh3mR3-AnCh6mR3**	0.9	0.62004	1.34355	0.45645	**0.001**
*** = Significant p value**						
RR - Retraction rate; AL - Anchorage loss; AnCh - Angular Changes; 3m - 3 months; 6m - 6months; R3 - 3mm power arm; R9 - 9mm power arm						

Fig 2-Comparison of canine retraction rate, Anchorage loss and Angular changes between 9mm and 3mm power armafter 3 and 6 months



Discussion:

Orthodontic treatment fundamentally seeks to enhance patients' quality of life through improvements in dentofacial aesthetics and functional occlusion. The core mechanism underlying this therapeutic approach is the orchestration of tooth movement via biomechanically induced remodeling processes within the alveolar complex. When controlled orthodontic forces are applied to teeth, they initiate a cascade of biological responses in the surrounding tissues. Specifically, these forces create areas of compression and tension within the periodontal ligament and adjacent alveolar bone. On the compression side, where the tooth is being pushed, osteoclastic activity is stimulated, leading to localized bone resorption. Conversely, on the tension side, where the periodontal fibers are stretched, osteoblastic activity is upregulated, resulting in new bone deposition. This differential remodeling of the alveolar bone facilitates the gradual and controlled displacement of teeth through the alveolar housing. The intricate balance between these resorptive and formative processes is crucial for achieving optimal tooth movement while maintaining periodontal health. Understanding these biomechanical and biological principles is essential for orthodontists to design effective treatment strategies that maximize desired tooth movements while minimizing potential adverse effects on the supporting structures. Moreover, this knowledge underscores the importance of precise force application and careful consideration of individual patient factors in treatment planning to ensure predictable and stable orthodontic outcomes[10] .

Even in severe skeletal discrepancies, achieving an aesthetically pleasing smile is often a key treatment goal. For prominent teeth, premolar extractions followed by controlled retraction of the labial segment are frequently employed. This retraction is a critical, meticulous process for successful treatment [10]. Physiologically, tooth movement rates indirectly reflect bone remodeling and turnover. Initially, a small, immediate movement takes place, then followed by a lag phase and a subsequent phase of constant movement.

Iwasaki et al.'s [11] observation of a lag phase during low-force, high-movement canine retraction suggests even root surface stress distribution. Predictable space closure, regardless of appliance, hinges on precise control over the center of rotation and biological response. This necessitates optimal force systems[12] .

Sia et al. [13] underscored the pivotal role of length of power arm in manipulating movement of tooth during retraction via sliding mechanics. By strategically varying the power arm's length relative to the tooth's center of resistance (CR), the investigators demonstrated alterations in the line of force application and moment of force. This ultimately enables precise control over crown angulation, ranging from lingual tipping to labial tipping or even bodily movement. Notably, when the power arm length coincides with the CR, the moment of force becomes nullified as the force vector acts directly through this point (moment = force x distance from CR).

Nikoli [14]defined optimal orthodontic force as a delicate balance, aiming to achieve the most favorable biological response (rapid tooth movement) with slightest tissue damage and discomfort. This force level minimizes hyalinization and maximizes osteoclastic activity. Optimal force recommendations vary: Smith and Storey[15] suggest 150-200gm for lower canines, while Reitan suggests 250gm, Lee 150-260gm, Profit 100gm, and Rickets et al. 75gm [14].

Nickel-titanium alloys have gained popularity in orthodontics since 1971 considering their distinctive characteristics of shape memory and superelasticity, with the super elastic property allowing an arch wire to exert consistent forces regardless of deflection distance[16].

SentalloyNi-ti closed coil springs, known for theircontinuous, light forces and superelasticity, are ideal for initial force application [14]. Reitan et al. advocate for lighter initial forces to promote desirable biological effects, minimizing hyalinized tissue and facilitating its replacement with healthy cells [17].In this study, Ni-ti closed coil spring with an exerting150 grams force was used. The springs produced more linear and predictable amount of space closure.

Canine retraction:

A two-step retraction approach offers advantages for achieving greater retraction of anterior teeth. By retracting canines independently followed by incisors, this method reduces anchorage loss by incorporating more teeth into the initial unit [18]. Additionally, individual canine retraction is more prone to tipping and rotation compared toanterior retraction as one unit [19]. However, controlled forces and a well-defined line of action can mitigate these unwanted tooth movements.

Expanding on the proposition by Melsen et al. [20] that genuine orthodontic translation occurs when the force vector passes through the tooth's center of resistance (CR), this study employed canine brackets with variable power arm lengths (6mm and 9mm) to approximate force application closer to the canine's CR, located approximately 8.2 mm apical to the alveolar crest, thereby minimizing unwanted tipping. The results demonstrated that the 9mm power arm achieved superior canine retraction with predominantly bodily movement, while the 6mm and 3mm arms produced increased space closure but with uncontrolled tipping. This suggests that force application in all cases fell below the predicted CR of the canine, highlighting the critical importance of precise force vector positioning in orthodontic biomechanics. These findings not only underscore the intricate relationship between biomechanical principles and clinical outcomes but also emphasize the potential for improved 23treatment efficiency through careful manipulation of power arm length. However, it is important to note that optimal arm length may vary based on individual patient factors such as root length, alveolar bone height, and tissue biotype, indicating a need for further research into personalized orthodontic appliances that account for these variables to further refine the precision of tooth movement in orthodontic treatment.

Our findings align with prior research. Hedayati et al. [21] used finite element analysis to show that a longer power arm promotes bodily tooth movement by minimizing uncontrolled tipping. Similarly, the 9mm power arm in this study achieved this effect. Furthermore, Tominaga et al. [22]elucidated a pivotal link between the location of force application relative to the tooth's center of resistance (CR) and the resulting angulation of the tooth structure. They elucidated that forces applied inferior to the CR induce lingual tipping, while superior application results in labial tipping. Notably, coinciding the force vector with the CR facilitates bodily movement. Ansari [23] subsequently built upon this foundation by investigating the power arm's efficacy in achieving bodily movement and concurrently optimizing its placement for this specific outcome. Their analysis revealed that the cervical third attachment yielded the most significant bodily movement, followed by the middle and incisal thirds.

Anchorage loss, characterized by the mesial migration of posterior teeth into extraction sites, is a multifactorial phenomenon in orthodontics influenced by various anatomical and biomechanical factors. These include the root surface area, root morphology, and the quantity of posterior teeth involved. To mitigate this undesired movement, orthodontists employ diverse anchorage reinforcement strategies. These approaches encompass expanding the anchorage unit by incorporating additional posterior teeth, utilizing auxiliary appliances such as transpalatal or Nance palatal arches, and more recently, integrating orthodontic mini-screws either directly or indirectly in the posterior region. These techniques aim to enhance the resistance to unwanted tooth movement, thereby preserving the space created by extractions for intended tooth movements. Interestingly, research by Silvia Geron [24] suggests that the magnitude of anchorage loss remains consistent regardless of whether canine retraction is performed individually or en masse. This finding has significant implications for treatment planning and mechanics design in orthodontic practice. It challenges the conventional wisdom that might favor one retraction method over another based solely on anchorage preservation concerns. Furthermore, this observation underscores the complex nature of tooth movement within the alveolar complex and highlights the need for comprehensive anchorage management strategies that consider not only the method of retraction but also patient-specific factors and overall treatment goals. As orthodontic techniques continue to evolve, a deeper understanding of these biomechanical principles becomes crucial for optimizing treatment outcomes and efficiency.

This investigation revealed statisticallyinsignificant difference in anchorage loss between 3mm, 6mm, and 9mm power arms. The findings of this study align with the observations of Patil et al. [25],who reported a lack of statistically significant anchorage loss when employing a 4.68 mm (Discopender 468) power arm compared to other groups.

Conclusion:

This study investigated a two-stage tooth retraction technique employing a power arm strategically positioned near the canine's center of resistance (CR). Results revealed that the 9mm power arm facilitated more rapid space closure compared to its 6mm counterpart, likely due to a more advantageous force vector relative to the estimated CR. Interestingly, anchorage loss remained comparable between different arm lengths when supplemented with a transpalatal arch and additional molar tie-in. These findings suggest that a 9mm power arm offers distinct advantages in terms of efficient space closure and bodily tooth movement during two-step or canine retraction procedures. This benefit persists despite the additional time required for soldering, which contributes to its enhanced structural stability. The implications of this research extend beyond mere efficiency gains, highlighting the intricate interplay between biomechanical design and clinical outcomes in orthodontics. By optimizing power arm length, practitioners may achieve more predictable and controlled tooth movements, potentially reducing overall treatment duration and improving patient outcomes. Furthermore, the study underscores the importance of considering anchorage reinforcement strategies in conjunction with power arm design to maximize treatment efficacy while minimizing undesired tooth movements. Future research could explore the potential for customized power arm designs tailored to individual patient anatomies, further refining the precision and predictability of orthodontic tooth movement in clinical practice.

Declaration of competing interest: The authors declare they have no conflicts of interest associated with this work.

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