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Relationship between specific temporomandibular disorders and impaired upper neck performance

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Upper neck impairments are more prevalent in patients with temporomandibular disorders (TMDs) but the differences between specific types of TMDs are unclear. This study evaluated the distribution of such impairments among different forms of TMD. In total, 116 participants (86 women and 30 men, age range 21–75 yr) were investigated. Forty-two individuals had no TMDs and were assigned to the control group. The remaining 74 patients were assigned to one of three groups based on the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) findings: pain-related (n = 37); intra-articular (n = 17); or mixed (combined pain-related and intra-articular) (n = 20). Analyses of impairments included between-group comparisons of key parameters of upper neck performance (active/passive mobility and muscular capabilities) and pain (subjective neck disability and pain sensitivity). Patients in the pain-related and mixed TMD groups were found to have decreased upper neck mobility in the cervical flexion-rotation test compared with patients in intra-articular and control groups, as well as poorer capabilities of the deep neck flexor muscles in the cranio-cervical flexion test compared to the control group. It was concluded that patients with pain-related TMD diagnoses are more likely to experience significant upper-neck hypomobility and poor muscular capabilities than patients with intra-articular diagnoses of TMD.

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Temporomandibular disorders (TMDs) are a group of conditions that cause pain and dysfunction in the masticatory muscles, the temporomandibular joint (TMJ), and their associated structures (1, 2). Temporomandibular disorders are very common among the general population, and comprise the second most-common musculoskeletal condition in the USA after chronic low back pain (2). According to epidemiological studies, approximately 10% of the adult worlwide population have TMDs, the majority being young women aged 20–40 yr (2). Neck pain, which is the most common cervical spine disorder, affects some 70% of people during their lifetime (3). It has been suggested that 40% of the population suffers from cervical pain annually, and that the point prevalence of neck pain is as high as 10%–20% of the general population (3, 4). The current literature supports a clear association between TMDs and cervical spine disorders (5, 6, 12–19).

The neurophysiological pain projection patterns between the upper neck and the facial region are strongly favored as the mechanism connecting TMDs and cervical spine disorders (8–10). By means of this mechanism, an afferent stimulation from any structure that is innervated by one of the upper three cervical nerve roots may be processed and potentially project pain with a trigeminal sensory distribution, thus involving the masticatory muscles. The proposed neuroanatomical mechanism for this projected pain from the upper neck to the face, and vice versa, is the neuroanatomical sensory input convergence that occurs in the trigeminocervical complex of the brainstem, which receives nociceptive input from both the upper neck and the trigeminal nerve (8, 10, 11). This input from the trigeminocervical complex is subject to a modulation from brainstem structures, such as periaqueductal gray matter, nucleus raphe magnus, and rostroventral medulla (11). These pain-modulating structures are considered to be involved in central sanitization as a result of persistent afferent stimulation of the trigeminocervical complex (11). Numerous studies have reported on specific measurable impairments of the cervical spine in patients with TMD (6, 12–22). Two of those impairments, which are mainly related to the upper neck, were consistently present in patients with TMD: one was reduced mobility, as mainly expressed in the cervical flexion-rotation test (18, 19, 21, 22); and the other was poor muscular performance of the deep cranio-cervical flexors (13–15, 18). Interestingly, addressing these upper neck impairments therapeutically has been reported to result in significant clinical improvement of the masticatory system (23–25).

A careful survey of the current literature failed to elicit any studies that analyzed the upper neck parameters according to a specific TMD diagnosis (e.g., pain-related TMD), but rather referred to all of the individuals with TMD collectively as a single homogenous group.

In 2014, after a longitudinal process of research and data analysis by the International Network for Orofacial Pain and Related Disorders Methodology (INfORM) (27), the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) was published, replacing the former version [Research Diagnostic Criteria for TMDs (RDC/TMD)] that had been published in 1992 (26–29). Compared with the RDC/TMD, this new diagnostic system provides more valid and reliable criteria for common TMDs for both clinical and research purposes (28, 30, 31). According to the DC/TMD, and unlike the RDC/TMD, the two primary and most prevalent specific groups of patients with TMD are referred to as having 'pain-related TMD' (pain as the main clinical problem) and 'intra-articular TMD' (temporomandibular disc displacement as the main problem). The main clinical difference between the RDC/TMD and the DC/TMD is that the latter includes an additional condition of pain modification during mastication as part of the diagnosis of pain-related TMD. Moreover, the refined diagnostic criteria for musculoskeletal disorder in the DC/TMD will probably exclude patients with pain disorders unrelated to the musculoskeletal system. Although a relatively high volume of research has assessed the association of cervical spine impairments in patients with TMDs (6, 7, 12–19, 21, 22), to the best of our knowledge none of these studies included patients diagnosed according to the updated DC-TMD. Therefore, the present study aimed to assess cervical spine impairments in patients with TMD using the new and improved DC/TMD, for what we believe to be the first time.'

Material and methods

Data for this study were collected at the Face & Jaw Pain Clinic of Tel-Aviv University between the beginning of May 2016 and the end of June 2018. The objectives of the study were described to all the participants, and all signed an informed consent. This study was approved by the Institutional Review Board of Tel Aviv University on 20 October 2015 (approval no.: 20141217_09280561).

Based on the DC/TMD guidelines (26, 27), only patients older than 18 yr of age and younger than 75 yr of age who were diagnosed with pain-related TMD and/or intra-articular TMD were included in the study. Patients with degenerative joint disorders (as evidenced by joint crepitus) or any other form of TMD were excluded. The control group consisted of students and staff members from the Schools of Dental Medicine and Health professions of Tel Aviv University, as well as patients attending the clinic who did not complain of dental pain or any TMD and did not meet the DC/TMD criteria (26, 27). The control group participants were free of any functional disorder of the masticatory system or complaints that could indicate its presence (such as pain or clicks during chewing) and had been so for the past year. The TMD assessment and classification were performed independently of the cervical spine examination by four senior faculty members at the Face & Jaw Pain Clinic of The School of Dental Medicine, Tel Aviv University (EW, SR, AEP, PFR), who had completed the DC/TMD Training and Calibration Course at the Department of Orofacial Pain and Jaw function at the Faculty of Odontology, Malmö University, Sweden. The training process for all the examiners was carried out prior to this study according the DC-TMD protocol and the examiners achieved high levels of interobserver reliability (28, 30, 31).

Based on the up-to-date DC/TMD (27), the main criteria for pain-related TMDs were: pain while chewing, and pain modified by jaw movement, function, or parafunction; confirmation of pain in the masticatory muscle(s) or in the TMJ as verified by the examiner; and pain in the masticatory muscle(s) or in the TMJ with either muscle palpation or maximum opening as verified by the examiner. The main criteria for intra-articular TMDs were TMJ noises that were objectively audible or reported by the patient in the past or during the examination, and click(s) that were objectively audible with mouth opening and closing and/or lateral movement. Based on these criteria, each patient with TMD was categorized into one of the following three specific TMD groups: 'pain-related'; 'intra-articular'; or 'mixed' (combined 'pain-related' and 'intra-articular').

All cervical spine examinations were carried out by a PhD student, a qualified senior physical therapist with a master's degree in musculoskeletal and sports physiotherapy and 15 yr of clinical practice in manual therapy of the cervical spine. The examiner was blinded to the group assignment of participants (i.e., study or control) and to the specific TMD diagnosis of each participant throughout the study. Assessment of the cervical spine was conducted in a specially assigned laboratory at the Steyer School of Health Professions of Tel Aviv University. Both performance (mobility and muscular capabilities) and pain parameters (subjective questionnaire and objective mechanical pain sensitivity) were assessed, with parameters evaluated performed in a random order using a simple randomization procedure.

Cervical range of motion, which is highly correlated with cervical disorders, was assessed using a cervical range of motion device (Performance Attainment Associates, Roseville, MN, USA) (Fig. 1), one of the most reliable and sensitive tools for measuring cervical spine mobility (32–36). The test was performed with the individual in a sitting position on a chair, with the trunk of the body touching the back of the chair and the feet resting on the floor. The participant was then instructed to perform the following six physiological cervical movements in random order using a simple randomization procedure: flexion, extension, right/left lateral flexion, and right/left rotation. Each movement was performed three times with an intervening interval of 30 s. The average of the three measurements (in degrees) was the final score for each individual movement.

Upper neck mobility was evaluated by the cervical flexion-rotation test using the cervical range of motion device. The cervical flexion-rotation test is considered the best clinical test for assessing relative isolated mobility of the

Fig. 1. The cervical range of motion device.

upper cervical spine (37–42). It has well-established high sensitivity and specificity in the diagnosis of cervicogenic headache (37, 39–41). For this examination, the cervical range of motion device was firmly attached to the head of the participant who lay supine on a treatment couch. The participant was asked to relax while the neck was moved by the examiner to the end of the cervical flexion range. In this flexed position, the head and neck were passively rotated as far as possible within comfortable limits of pain or physiological stiffness. End of range was determined either by firm resistance encountered by the therapist or the participant reporting the onset of pain, whichever came first. The intention was to measure range of motion irrespective of cause of limitation, in the least provocative manner, to prevent potential exacerbation of symptoms.

The range was recorded and repeated twice more to either side, with 30 s of rest between the tests. The finding was considered positive when the range of motion to at least one of the sides was smaller than 32°. The average of three range of motion measurements made to each side was calculated, representing the final scores for left and right ranges of motion.

Upper neck muscular capabilities were assessed by the cranio-cervical flexion test using pressure biofeedback. This valid and reliable (43) clinical test records the endurance of the cranio-cervical flexors musculature (deep neck flexors). Impaired performance of the deep neck flexors is associated with the diagnosis of cervicogenic headache (44). Cranio-cervical flexion is flexion of the head over the upper cervical region without any flexion of the middle or lower cervical region (45). The cranio-cervical flexion test was performed with the participant in a supine position, with 45° hip flexion and 90° knee flexion. A feedback device, termed the 'stabilizer' (Chattanooga Group, Hixson, TN, USA), was applied under the suboccipital region and inflated to 20 mmHg of pressure, and the subjects were instructed to bend their heads, as if to say 'yes', in order to obtain an examiner-approved cranio-cervical flexion movement. The movement was taught to each participant and practiced before the test to ensure that cranio-cervical flexion was performed correctly.

The deep neck flexors activation score and the deep neck flexors performance score were measured in two phases: muscular activation and muscular performance. The deep neck flexors activation score (0–10) represents the highest target pressure that a participant can achieve and hold for 10 s, starting at a baseline of 20 mmHg and increasing by 2 mmHg at each phase, with a total of five phases and a top value of 30 mmHg (target pressures of 22, 24, 26, 28, and 30 mmHg). The feedback device provided information to the examined subjects regarding the performance of the target pressure during the 10 s hold. There was a rest of 10 s (within the baseline level of 20 mmHg) between phases in order to determine the pressure (in mmHg) that the participant could achieve with the correct movement pattern held for 10 s. When the participant could not perform the correct movement, the test was terminated and the pressure registered was the greatest pressure at which the participant performed the correct movement without substitution, which corresponded to the previous phase. The deep neck flexors activation score (0–10 index) represents the strength and accuracy of the deep cervical flexors muscles recruited (43, 45). Based on this score (22, 24, 26, 28, or 30 mmHg), the participant was asked to repeat it by executing several 10-s holds with 3–4 s of rest between. This part was halted when the correct movement pattern could not be controlled by the participant up to a maximum of 10 repetitions. The performance score was 100 ($10 \times 10 = 100$) when the activation score was 10 and the participant could properly execute 10 repetitions. The deep neck flexors performance score is considered to represent the endurance and strength capacity of the deep cervical flexors (43, 45).

Cervical spine pain was assessed using the neck disability index. The participants completed this neck pain condition-specific functional status questionnaire which requests information on the following 10 items: pain; personal care; lifting; reading; headaches; concentration; work; driving; sleeping; and recreation. The neck disability index is considered as being the most reliable and valid subjective disability index for people with neck pain disorders (46–49).

Algometric pain pressure threshold (PPT) measurements of the cervical spine were performed using a hand-held pressure algometer (Algometer type II; Somadic Sales, Solna, Sweden). Patients with a cervical disorder have been shown to have higher sensitivity to mechanical pressure than healthy controls (13, 14, 50, 51). Before the PPT measurements, each patient underwent a short training session for familiarization with the algometer and its application. All sites were then palpated, located, and marked. For testing the mechanical sensitivity of both lower and upper neck anatomical landmarks along the articular pillar, three homologous cervical pairs (six individual sites in all) were measured as follows: C2, 2 cm lateral to the spinous process of the second cervical vertebra (over the greater occipital nerve); C4, 1–2 cm anterior to the trapezius ridge; and C6, 1–2 cm posterior to the trapezius ridge. The pressure was applied at a constant rate of approximately 1 kg cm^{-2} s^{-1} until the subjects reported a change of sensation from pressure to pain. This procedure was repeated three times to confirm accuracy. As a control, a distant anatomical point (right tibialis anterior muscle) was also measured using the same procedure. The tibialis anterior site was determined by measuring the midpoint between the fibular head and the medial malleolus, and the PPT was tested with the participant in the supine position.

Statistical analysis

All data were collected in the Face & Jaw Pain Clinic and downloaded directly into an Excel spreadsheet. IBM SPSS Statistics for Windows, version 22.0 (IBM, Armonk, NY, USA) was used for statistical analyses. One-way ANOVA was used with an additional Tukey post-hoc test (a modified Bonferroni approach) as a single-step multiple comparison to analyze and compare the upper neck performance (cervical range of motion, flexion-rotation test, and cranio-cervical flexion test) and pain (neck disability index and pressure pain threshold) parameters of the specific TMD groups and the healthy controls. Tukey's test calculates a new critical value that can be used to evaluate whether differences between any two pairs of means are significant. Each difference is then compared with the Tukey critical value. If the difference is larger than the Tukey value, the comparison is significant. The Pearson correlation coefficient was used to assess and analyze the correlations between the cervical spine and TMD performances and the pain parameters. As multiple ANOVAs were carried out for the different cervical spine performance and pain parameters, a modified value of $P < 0.005$ was considered statistically significant (0.05 divided by the number of ANOVAs).

Results

The data on all 116 participants were retrieved, and the results were analyzed for the three specific TMD groups: 'pain-related' (n = 37); 'intra-articular' (n = 17); and 'mixed' (n = 20). The findings for the TMD groups were compared with those for the control group (n = 42). The mean age of all participants was 34.2 ± 12.3 yr, with no significant age difference between the groups (Table 1). Most of the 116 participants were women (n = 86, 74%), and there was no statistically significant sex difference between the groups (Table 1).

Table 1

Distribution of age and gender across the groups examined

Group	n	Age (yr) (mean ± SD)	Female n (%)
Pain-related TMD	37	34.1 ±11.8	29 (78)
Intra-articular TMD	17	32.0 ±12.6	11 (64)
Mixed TMD	20	39.0 ±14.3	17 (85)
Healthy	42	32.0 ±11.0	29 (69)
Total	116	34.2 ±12.3	86 (74)

TMD, temporomandibular disorder.

Testing for upper neck mobility revealed significant differences between the specific TMD groups for both right and left flexion-rotation tests ($P < 0.005$) (Table 2). The upper neck mobility in patients of pain-related and mixed TMD groups was more limited than that of patients in the intra-articular study group and the control group. In the majority of patients with pain-related and mixed TMD, the end of range limiting factor of the flexion-rotation test was pain (pain-related TMD group: 73% to the right and 64% to the left; mixed TMD group: 65% to the right and 60% to the left) whereas in most of the patients with intra-articular TMD, the limiting factor was firm resistance (88% to the right and 94% to the left), similarly to healthy controls (95% to the right and 93% to the left) (Table 2). Upper neck muscular capabilities were significantly different among the specific TMD groups for both activation and performance of deep neck flexors ($P < 0.005$) (Table 3). The pain-related and mixed TMD groups (but not the intra-articular group) had poorer performances in these parameters compared with the control group.

Pain-related and mixed TMD groups, but not the intra-articular TMD group, showed an impaired neck disability index score compared with the control group ($P < 0.005$). No significant differences were found between the groups for any of the six cervical spine pressure pain threshold anatomical points.

There were no statistically significant differences (at $P < 0.005$) between the specific TMD groups for the following general cervical spine mobility parameters (Table 4): extension, right lateral flexion, and right and left rotation. Although not meeting the modified level of significance, both the pain-related and mixed TMD groups were consistently limited in these parameters compared with the intra-articular TMD study group and the control group.

Table 2

Descriptive statistics for upper neck mobility, assessed using the cervical flexion-rotation test (FRT)

FRT	Group	n	Mean range of motion (°)	SD	Pain as limiting actor (%)	95% CI	Between-group mean difference (95% CI)*
Right FRT	**Pain-related TMD**	**37**	**28**	**8**	**73**	**25–30**	**11 (6, 16)**
	Intra-articular TMD	17	38	7	12	35–42	1 (−4, 7)
	Mixed TMD	**20**	**29**	**11**	**65**	**23–43**	**10 (4, 16)**
	Healthy	42	39	6	5	38–41	–
Left FRT	**Pain-related TMD**	**37**	**26**	**5**	**64**	**24–28**	**11 (6, 15)**
	Intra-articular TMD	17	34	10	6	28–39	3 (−2, 8)
	Mixed TMD	**20**	**22**	**8**	**60**	**18–25**	**10 (4, 16)**
	Healthy	42	37	6	7	35–39	–

For groups in bold face the estimates were statistically significantly different from those of controls at $P < 0.005$.
TMD, temporomandibular disorder.
*Between-group differences (control group – TMD group).

Table 3

Descriptive statistics for upper neck muscular capabilities, assessed using the cranio-cervical flexion test

Cranio-cervical flexion test	Group	*n*	Mean score	SD	95% CI	Between-group mean differences (95% CI)[‡]
Deep neck flexors activation score*	**Pain-related TMD**	**37**	**5.3**	**3.0**	**4.3–6.3**	**2 (0.6, 4.0)**
	Intra-articular TMD	17	7.2	2.8	5.8–8.7	0.4 (−1.7, 2.6)
	Mixed TMD	**20**	**4.6**	**2.9**	**3.2–5.9**	**0.7 (1.0, 5.1)**
	Healthy	42	7.7	2.8	6.8–8.6	–
Deep neck flexors performance score[†]	**Pain-related TMD**	**37**	**28.6**	**36.3**	**16.5–40.7**	**30.6 (8.8, 52.4)**
	Intra-articular TMD	17	56.1	38.7	36.1–76.0	3.2 (−24.5, 30.0)
	Mixed TMD	**20**	**21.5**	**30.2**	**7.3–35.6**	**37.8 (11.5, 64.1)**
	Healthy	42	59.3	39.7	46.9–71.7	–

For groups in bold face the estimates were statistically significantly different from the control group at $P < 0.005$.
TMD, temporomandibular disorder.
*The deep neck flexors activation score (0–10 index) represents the highest target pressure that a subject can achieve and hold for 10 s.
[†]The deep neck flexors performance score (0–100 index) represents the highest target pressure that a subject can achieve and hold for 10 s multiplied by the number of holding repetitions (up to 10).
[‡]Between-group differences (control group – TMD group).

Discussion

Upper neck impairments are more prevalent in patients with TMDs, but differences in these impairments between specific types of TMD have not been clearly defined. The aims of this study were to describe the distribution of such impairments among three types of TMDs based on the updated DC/TMD criteria and to compare the results with those obtained from a comparable-age non-TMD control group: significant impairments were found among the 'pain-related' and 'mixed' TMD groups but not in the 'intra-articular' and control groups.

Unlike earlier studies that assessed cervical spine performance and pain parameters of patients with TMD, the current study used the updated DC/TMD (26, 27) for selecting the study participants. Compared with its predecessor, RDC/TMD, the current diagnostic criteria for TMD is an evidence-based diagnostic system with

Table 4

Descriptive statistics for the groups and between-group differences for general neck mobility

Type of cervical motion	Group	*n*	Mean score (°)	SD	95% CI	Between-group mean differences (95% CI)*
Flexion	Pain-related TMD	37	53	9	50–56	5 (−1, 11)
	Intra-articular TMD	17	61	11	55–67	−2 (−10, 5)
	Mixed TMD	20	52	14	45–59	5 (−1, 13)
	Control	42	58	9	55–61	–
Extension	Pain-related TMD	37	62	15	57–68	9 (1, 18)
	Intra-articular TMD	17	75	10	69–81	−2 (−13, 8)
	Mixed TMD	20	62	19	53–71	10 (0, 20)
	Control	42	72	12	68–76	–
Right lateral flexion	Pain-related TMD	37	38	8	35–41	7 (1, 12)
	Intra-articular TMD	17	46	8	42–50	0 (−7, 6)
	Mixed TMD	20	38	11	32–43	7 (1, 14)
	Control	42	45	8	43–48	–
Left lateral flexion	Pain-related TMD	37	42	8	39–45	5 (0, 10)
	Intra-articular TMD	17	45	9	40–51	1 (−6, 8)
	Mixed TMD	20	43	13	36–49	4 (−2, 11)
	Control	42	47	9	44–50	–
Right rotation	Pain-related TMD	37	61	8	58–64	6 (0, 12)
	Intra-articular TMD	17	66	8	61–70	2 (−5, 9)
	Mixed TMD	20	57	14	51–64	10 (3, 17)
	Control	42	68	8	65–71	–
Left rotation	Pain-related TMD	37	64	10	60–67	6 (0, 12)
	Intra-articular TMD	17	67	8	63–72	3 (−4, 10)
	Mixed TMD	20	62	14	55–69	8 (1, 16)
	Control	42	70	8	68–73	–

For groups in bold face the estimates were statistically significantly different from the control group at $P < 0.005$.
TMD, temporomandibular disorder.
*Between-group differences (control group – TMD group).

higher validity for clinical use (29, 30, 51). Therefore, the application of DC/TMD as the primary tool in the current study enhances the external validity of the findings.

It was clear that patients with 'pain-related' TMD (with or without 'intra-articular' TMD) were limited in upper cervical spine performance compared with controls. The cervical flexion-rotation test indicated limited mobility in both sides of the upper neck as well as impairment of the activation and performance of deep neck flexors. On the other hand, the upper cervical spine performances of patients with 'intra-articular' TMD (i.e., those with an isolated intra-articular disorder) were similar to those of the controls. Although numerous studies have already assessed upper cervical spine parameters of patients with TMD (5, 13–15, 18–22, 34), the present study is the first to compare these cervical spine parameters between specific groups of patients diagnosed according to the latest DC/TMD. Interestingly, a recent study which assessed the upper neck performance of women with painful TMD diagnosed according the RDC-TMD, reported impaired neck mobility and muscular performance, which is similar to the findings presented in this study (5).

As the experience of pain is often associated with significant motor impairment (4, 43), it is suggested that the findings of this study may be explained by the convergence of noxious stimuli from the upper cervical spine and masticatory structures into the same neuroanatomical structure, the trigeminocervical complex. Thus, experiencing pain in the masticatory system may affect the mobility and strength of the upper neck via somatic referred pain mechanisms. The fact that mainly the upper neck (and not the general neck) performance parameters (as assessed using the flexion-rotation test and the cranio-cervical flexion test) were highly impaired in patients with 'pain-related' TMD may lend credence to the trigeminocervical complex convergence theory (8, 9, 52). Another finding which supports this connecting mechanism is that pain was the main limiting factor in the cervical flexion-rotation test among patients with pain-related TMD, while resistance was the dominant limiting factor among patients with intra-articular TMD (Table 3). According to the trigeminocervical complex convergence theory, and as supported by previous studies (8, 10), patients with 'painful' TMD are expected to present a significantly higher sensitivity in their upper cervical spine compared with comparable non-TMD controls. However, there were no significant differences in the pressure pain threshold among the TMD subgroups in the present study, although the patients with TMD tended to be more sensitive than the controls.

The main limitation of this study is the relatively small size of the 'intra-articular TMD' group ($n = 17$), which reduces the external validity of the between-group findings and therefore should be viewed with caution. Within this limitation, it is concluded that only patients diagnosed according to the DC/TMD as having 'pain-related' TMD – and not those with an isolated intra-articular dysfunction – experience objectively validated impaired mobility and muscular performance around their upper cervical spine. Taken together, the important clinical implication of this study is that the upper neck of patients with 'pain-related' TMD should be routinely assessed and managed accordingly by a specialized musculoskeletal practitioner with expertise in cervical spine rehabilitation.

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Conflict of interest – None.

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