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Occupation-Related Cervical Mobility Patterns in Dentists: A Cross-Sectional Comparison with Office Workers

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Research Article

Keywords: Dentists, Cervical spine, Range of motion, Movement asymmetry, Neck Disability Index, Occupational ergonomics

Posted Date: September 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10800122/v1

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Additional Declarations: No competing interests reported.

Abstract

Objectives

To compare cervical range of motion (ROM) and movement asymmetry between dentists and office workers, examine whether these characteristics differ according to professional experience in dentistry, and investigate their associations with neck-related disability.

Materials and methods

This cross-sectional comparative study included 59 participants: 19 experienced dentists (> 5 years of clinical practice), 20 early-career dentists (≤ 5 years), and 20 office workers. Active cervical ROM was assessed in flexion, extension, bilateral lateral flexion, and bilateral axial rotation using smartphone-based applications. Directional and absolute asymmetry were calculated for lateral flexion and rotation. Neck-related disability was assessed using the Neck Disability Index (NDI). Between-group differences were examined using appropriate parametric or non-parametric tests, followed by multivariable analyses adjusted for age, sex, and weekly physical activity.

Results

Cervical extension was lower in experienced and early-career dentists than in office workers (55.6 ± 7.2°, 59.5 ± 7.9°, and 65.5 ± 5.2°, respectively; $p < 0.001$), whereas left lateral flexion was greater in both dentist groups (48.8 ± 5.5°, 47.3 ± 5.8°, and 42.1 ± 3.9°; $p < 0.001$). Directional lateral-flexion asymmetry also differed between groups ($p = 0.001$), reflecting relatively greater left-sided mobility in dentists, while absolute lateral-flexion asymmetry did not differ significantly. The principal differences in extension, left lateral flexion, and directional asymmetry persisted after adjustment for age, sex, and physical activity. NDI scores were generally low (median 2.0 [IQR 0–4]). Associations of lower extension and greater absolute lateral-flexion asymmetry with higher NDI did not remain significant after false-discovery-rate correction in the primary analyses. Occupational workload was not significantly associated with cervical movement outcomes or NDI.

Conclusions

Dentists demonstrated a direction-specific cervical movement profile characterized by reduced extension, greater left lateral flexion, and directional lateral-flexion asymmetry rather than generalized mobility restriction. These differences were evident even among early-career dentists and occurred in the presence of minimal neck-related disability.

Clinical relevance

Occupation-related cervical movement differences may emerge early in dental practice. Prospective studies incorporating direct assessment of working posture are needed to determine their clinical significance and potential relevance to ergonomic prevention.

Introduction

Work-related musculoskeletal disorders are highly prevalent among dental professionals and represent an important occupational health concern. The neck is consistently among the most frequently affected anatomical regions, with systematic reviews and meta-analyses reporting a high prevalence of neck-related musculoskeletal complaints among dentists and other dental healthcare professionals [1–3]. Clinical dentistry requires prolonged visual concentration within a restricted operating field while performing precise manual procedures, frequently necessitating sustained or repeated cervical flexion, lateral bending, and rotation. Awkward working postures, prolonged clinical exposure, repetitive tasks, and high patient workload have all been identified as occupational factors associated with neck complaints in dental professionals [1,3,4,16]. Prolonged static and non-neutral working postures are of particular ergonomic concern, as dental procedures may require sustained positioning of the head and trunk for extended periods [15,17]. These findings suggest that the specific biomechanical demands of dental practice may impose a substantial and distinctive burden on the cervical region.

Most research on work-related neck disorders in dentists has focused on the prevalence of pain, self-reported musculoskeletal symptoms, and ergonomic risk factors [1–4,16]. However, objective kinematic studies have also demonstrated prolonged non-neutral head and trunk postures during dental treatment [15], suggesting that occupational exposure may be reflected not only in symptoms but also in measurable alterations in cervical motor function. Zhou et al. demonstrated that dentists not only had a higher prevalence of neck pain than non-dental professional controls but also exhibited measurable differences in cervical mobility, including extension, lateral flexion, and rotation [5]. More recently, longitudinal observations in dental students have demonstrated changes in cervical muscle activation patterns during the initial period of clinical training, further supporting the possibility that exposure to dental work may be accompanied by measurable changes in cervical motor function [6]. Together, these findings highlight the potential value of objective assessment of cervical mobility alongside self-reported symptoms and disability.

Despite this evidence, the characteristics and clinical relevance of occupation-related cervical movement patterns in dentists remain incompletely understood. In particular, relatively little is known about whether dental professionals exhibit directional movement asymmetry, whether cervical mobility characteristics differ according to professional experience, and whether objectively measured movement characteristics are associated with neck-related disability. Office workers provide a clinically relevant comparison group because both occupations involve prolonged sedentary work, whereas dental practice additionally requires sustained and frequently asymmetric positioning of the head and neck to maintain visual and manual access to the oral cavity. Comparing these occupational groups may therefore help

characterize cervical movement patterns associated specifically with the biomechanical demands of dental practice rather than with sedentary work alone.

The primary objective of this study was to compare cervical range of motion and movement asymmetry between dentists and office workers and to examine whether these characteristics differed according to professional experience in dentistry. A secondary objective was to investigate the associations of cervical mobility and movement asymmetry with self-reported neck-related disability. We hypothesized that dentists would demonstrate reduced cervical range of motion and greater movement asymmetry compared with office workers, with more pronounced alterations among dentists with longer professional experience. We further hypothesized that greater cervical movement restriction and asymmetry would be associated with higher neck-related disability.

Materials and Methods

2.1 Study design, setting, and participants

This cross-sectional comparative observational study evaluated cervical mobility, movement asymmetry, and neck-related disability among dentists at different stages of professional experience and office workers. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations [7].

Sixty volunteers were recruited into three groups: experienced dentists with more than 5 years of continuous clinical practice, early-career dentists with 5 years or less of clinical practice, and office workers serving as a comparison group. Dentists were recruited from the Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, whereas office workers were recruited from the local community.

Participants were eligible if they were aged 18–60 years, had no diagnosed cervical spine pathology, reported no clinically significant neck pain during the preceding week, and were able to perform active cervical movements. Exclusion criteria included a history of cervical spine surgery or significant cervical trauma, cervical radiculopathy or myelopathy, neurological disorders affecting cervical function, and any other condition that could limit active cervical range of motion (ROM).

2.2 Ethical considerations and sample size

The study protocol was approved by the Institutional Ethics Committee of the Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University (approval No0008846-3). All participants provided written informed consent before participation. The study was conducted in accordance with the Declaration of Helsinki.

Before recruitment, sample size was estimated assuming a moderate between-group effect, a two-sided significance level of $\alpha = 0.05$, and 80% statistical power. Based on these assumptions and previous occupational musculoskeletal studies, approximately 15–20 participants per group were considered

sufficient for this exploratory three-group comparison. A target of 20 participants per group was therefore selected, yielding a planned sample of 60 participants.

2.3 Participant and occupational characteristics

Participants completed a demographic and occupational questionnaire that included age, sex, occupation, weekly physical activity, and typical sleeping position. Dentists additionally reported years of clinical practice, average clinical working hours per week, number of working weeks per year, and dental specialty, where applicable.

For dentists, cumulative occupational exposure was estimated as the total number of clinical working hours over their professional career. This variable was calculated by multiplying the average number of clinical working hours per week by the number of working weeks per year and the number of years in clinical practice. The resulting value, expressed in estimated cumulative clinical working hours, was used to examine the association between occupational exposure and cervical ROM, movement asymmetry, and neck-related disability.

2.4 Cervical outcome assessment

Cervical outcomes included self-reported neck-related disability, active cervical ROM, and movement asymmetry.

Neck-related disability. Neck-related disability was assessed using the Neck Disability Index (NDI), one of the most widely used and extensively validated patient-reported outcome measures for neck-related pain and disability [8,9]. The NDI has demonstrated acceptable test–retest reliability, construct validity, and responsiveness across different neck-related populations [9]. It consists of 10 items addressing pain and its impact on daily activities, with each item scored from 0 to 5, yielding a total score ranging from 0 to 50. Higher scores indicate greater neck-related disability.

Cervical range of motion. Active cervical ROM was assessed in six directions: flexion, extension, right and left lateral flexion, and right and left axial rotation. Flexion, extension, and lateral flexion were measured using the Clinometer + bubble level smartphone application (Peter Breitling, plaincode, Germany), whereas axial rotation was assessed using the built-in Compass application (Apple Inc., Cupertino, CA, USA).

All measurements were obtained using the same iPhone 13 device (Apple Inc., Cupertino, CA, USA) to avoid inter-device variability. Smartphone-based applications have demonstrated acceptable reliability and validity for assessing cervical ROM [10–13]. A systematic review and meta-analysis found good-to-excellent intra- and inter-rater reliability and moderate-to-very-high validity across different types of smartphone applications, although the certainty of evidence varied according to the application and measurement plane [10]. Clinometer-based applications have demonstrated acceptable measurement properties for sagittal- and frontal-plane cervical movements, whereas compass-based applications have also been used to assess axial rotation [11–13].

Participants were seated upright with the thoracic spine supported against the back of the chair, feet flat on the floor, hands resting on the thighs, and the head initially positioned in a self-selected neutral position. The smartphone was calibrated before each movement direction (Fig. 1). Participants performed one familiarization trial with the same investigator (NS) followed by three recorded repetitions. The mean of the three measurements was used for statistical analysis. Each movement was performed actively to the maximal pain-free range or until firm resistance was perceived.

Cervical movement asymmetry. Movement asymmetry was calculated separately for axial rotation and lateral flexion directly from the corresponding right- and left-sided ROM measurements. Directional asymmetry was calculated as:

Directional asymmetry = right ROM − left ROM

Positive and negative values therefore indicated the direction of the side-to-side difference. Absolute asymmetry, representing the magnitude of the difference irrespective of direction, was calculated as:

Absolute asymmetry = |right ROM − left ROM|

Directional and absolute asymmetry were analyzed separately because they represent different aspects of cervical movement: the former describes the direction of the side-to-side difference, whereas the latter describes its magnitude.

Measurement standardization. All cervical ROM assessments were performed by a single examiner (NS), a final-year dental student who underwent standardized training under the direct supervision of an experienced musculoskeletal physiotherapist (TG) with more than 15 years of clinical experience in cervical spine assessment. Before participant recruitment, the examiner completed repeated supervised practice of the full measurement protocol to standardize participant positioning, device placement, calibration, and movement instructions. The use of a single examiner avoided potential inter-examiner variability during data collection.

2.5 Statistical analysis

Statistical analyses were performed using R (version 4.5.2). Continuous variables were summarized as mean ± standard deviation or median and interquartile range, as appropriate, and categorical variables as frequencies and percentages. Data distributions and the assumptions required for parametric analyses were assessed using graphical inspection and appropriate statistical tests.

Between-group differences were examined using one-way analysis of variance (ANOVA) when parametric assumptions were met. Welch's ANOVA was used when variances differed between groups, and the Kruskal–Wallis test was used for outcomes with substantially non-normal distributions. When a significant overall group difference was identified, pairwise comparisons were performed using Holm-adjusted comparisons following standard ANOVA, Games–Howell tests following Welch's ANOVA, and Dunn tests with Holm adjustment following Kruskal–Wallis tests.

Effect sizes were reported as η^2 for omnibus ANOVA effects and Hedges' *g* for relevant pairwise comparisons, together with 95% confidence intervals where appropriate.

Secondary multivariable linear regression analyses were used to determine whether observed differences in cervical movement between occupational groups persisted after accounting for potential confounding factors, including age, sex, and weekly physical activity. Regression coefficients (*B*) and corresponding 95% confidence intervals (CI) were reported. Robust standard errors were used when heteroscedasticity was present.

Associations between cervical movement characteristics and NDI were examined primarily using Spearman rank correlations because of the non-normal distribution of NDI scores. The Benjamini–Hochberg false-discovery-rate (FDR) procedure was applied to account for multiple correlation analyses. Pearson correlations were additionally performed as sensitivity analyses to assess whether the findings were influenced by the choice of correlation method.

Among dentists, associations between professional exposure variables, cervical movement characteristics, and NDI were examined as exploratory analyses.

All statistical tests were two-sided, and statistical significance was set at $p < .05$. Adjusted *p* or *q* values were used where correction for multiple comparisons was applied.

Results

3.1 Participant characteristics

Sixty participants were recruited. One participant from the experienced-dentist group was excluded from the analysis because his age (68 years) exceeded the predefined eligibility criterion of 18–60 years. The final analytical sample comprised 59 participants: 19 experienced dentists, 20 early-career dentists, and 20 office workers.

Participant characteristics are presented in Table 1. Experienced dentists were older than both early-career dentists and office workers (40.1 ± 7.1, 32.1 ± 3.1, and 31.9 ± 6.0 years, respectively; $p < .001$), whereas early-career dentists and office workers were similar in age. No significant between-group differences were observed in sex distribution, hand dominance, or weekly physical activity.

Table 1
Participant characteristics according to occupational group

Characteristic	Experienced dentists (n = 19)	Early-career dentists (n = 20)	Office workers (n = 20)	*p*
Age, years	40.1 ± 7.1	32.1 ± 3.1	31.9 ± 6.0	< .001
Female sex, n (%)	10 (52.6)	11 (55.0)	10 (50.0)	.951
Right-handed, n (%)	16 (84.2)	16 (80.0)	17 (85.0)	.903
Weekly physical activity	3.0 [2.0–4.0]	2.0 [1.0–3.0]	2.5 [1.8–3.0]	.403

Values are mean ± SD, median [IQR], or n (%), as appropriate.

3.2 Cervical range of motion

Cervical ROM differed significantly between occupational groups for extension and left lateral flexion, whereas no significant group differences were observed for flexion, right or left rotation, or right lateral flexion (Table 2; Fig. 2A–B).

Extension demonstrated a significant overall group effect (F (2,56) = 10.25, p < .001, η^2 = .268). Experienced dentists had lower extension than office workers (55.6 ± 7.2° vs 65.5 ± 5.2°; Holm-adjusted p < .001; Hedges' g = − 1.54). Early-career dentists also demonstrated lower extension than office workers (59.5 ± 7.9° vs 65.5 ± 5.2°; adjusted p = .014; g = − 0.88). The difference between experienced and early-career dentists was not significant (adjusted p = .122).

A significant overall group effect was also observed for left lateral flexion (F (2,56) = 9.21, p < .001, η^2 = .247). Experienced dentists demonstrated greater left lateral flexion than office workers (48.8 ± 5.5° vs 42.1 ± 3.9°; adjusted p < .001; g = 1.37), as did early-career dentists (47.3 ± 5.8° vs 42.1 ± 3.9°; adjusted p = .004; g = 1.04). The two dentist groups did not differ significantly (adjusted p = .444).

No significant group differences were identified for flexion (p = .952), right rotation (p = .439), left rotation (p = .485), or right lateral flexion (p = .099).

3.3 Cervical movement asymmetry

Directional lateral-flexion asymmetry differed significantly between groups (Welch's F (2,35.4) = 8.27, p = .001; Fig. 2C). Mean right-minus-left asymmetry was − 2.35 ± 3.64° in experienced dentists, − 0.72 ± 2.77° in early-career dentists, and + 1.33 ± 2.16° in office workers. Games–Howell pairwise comparisons showed a significant difference between experienced dentists and office workers (mean difference − 3.68°, p = .002) and between early-career dentists and office workers (mean difference − 2.05°, p = .034). No significant difference was observed between the two dentist groups (p = .271).

In contrast, absolute lateral-flexion asymmetry did not differ significantly between groups (Kruskal–Wallis p = .188). Neither directional rotation asymmetry (p = .101) nor absolute rotation asymmetry (p =

.069) demonstrated a significant overall group difference.

Table 2
Cervical range of motion and movement asymmetry according to occupational group

Outcome	Experienced dentists	Early-career dentists	Office workers	*p*
Flexion, °	59.3 ± 6.9	59.2 ± 5.4	58.7 ± 6.4	.952
Extension, °	55.6 ± 7.2	59.5 ± 7.9	65.5 ± 5.2	< .001
Right rotation, °	72.8 ± 6.9	75.5 ± 7.4	74.7 ± 5.9	.439
Left rotation, °	71.0 ± 6.3	69.8 ± 6.3	72.2 ± 6.4	.485
Right lateral flexion, °	46.4 ± 5.7	46.6 ± 5.6	43.4 ± 3.9	.099
Left lateral flexion, °	48.8 ± 5.5	47.3 ± 5.8	42.1 ± 3.9	< .001
Directional rotation asymmetry, °	1.81 ± 5.90	5.78 ± 6.25	2.47 ± 4.22	.101
Absolute rotation asymmetry, °	4.93 ± 3.55	6.85 ± 4.99	4.00 ± 2.72	.069
Directional lateral-flexion asymmetry, °	−2.35 ± 3.64	−0.72 ± 2.77	1.33 ± 2.16	.001
Absolute lateral-flexion asymmetry, °	3.44 ± 2.57	2.12 ± 1.87	2.07 ± 1.43	.188

Values are mean ± SD. Directional asymmetry was calculated as right minus left ROM; negative values indicate relatively greater left-sided ROM.

3.4 Neck-related disability

NDI scores were low across the sample, with an overall median of 2.0 [IQR 0–4]. Nineteen participants (32.2%) had an NDI score of 0, and 78.0% had scores between 0 and 4.

A modest overall difference in NDI distribution was observed between groups (Kruskal–Wallis $H = 6.11$, $p = .047$). Median NDI scores were 3.0 [1.5–5.0] in experienced dentists, 1.5 [0–5.0] in early-career dentists, and 0 [0–3.0] in office workers. Dunn pairwise comparisons with Holm adjustment showed a significant difference between experienced dentists and office workers (adjusted $p = .041$); the remaining pairwise comparisons were not significant.

3.5 Adjusted analyses

Secondary multivariable analyses were performed to examine whether the principal between-group cervical movement differences persisted after adjustment for age, sex, and weekly physical activity (Table 3).For cervical extension, experienced dentists demonstrated 7.60° less ROM than office workers (adjusted $B = -7.60°$, 95% CI − 12.74 to − 2.46; $p = .005$), while early-career dentists demonstrated 5.84°

less extension (adjusted *B* = − 5.84°, 95% CI − 10.11 to − 1.56; *p* = .008). Age showed a borderline inverse association with extension (*B* = − 0.31° per year; *p* = .060). The model explained 33.0% of the variance (R^2 = .330).

For left lateral flexion, experienced dentists demonstrated 7.02° greater ROM than office workers (adjusted *B* = 7.02°, 95% CI 3.17–10.86; *p* < .001), and early-career dentists demonstrated 5.43° greater ROM (adjusted *B* = 5.43°, 95% CI 2.23–8.63; *p* = .001). Age was not independently associated with left lateral flexion. The model explained 31.8% of the variance (R^2 = .318).

The directional lateral-flexion difference also persisted after adjustment. Relative to office workers, the right-minus-left difference was − 3.16° in experienced dentists (adjusted *B* = − 3.16°, 95% CI − 5.74 to − 0.58; *p* = .016) and − 2.09° in early-career dentists (adjusted *B* = − 2.09°, 95% CI − 3.64 to − 0.54; *p* = .008). The model explained 25.6% of the variance (R^2 = .256).

Table 3
Adjusted differences in cervical movement outcomes relative to office workers

Outcome	Group	Adjusted *B*, ° (95% CI)	*p*	Model R^2
Extension	Experienced dentists	−7.60 (− 12.74 to − 2.46)	.005	.330
	Early-career dentists	−5.84 (− 10.11 to − 1.56)	.008	
Left lateral flexion	Experienced dentists	7.02 (3.17 to 10.86)	< .001	.318
	Early-career dentists	5.43 (2.23 to 8.63)	.001	
Directional lateral-flexion asymmetry	Experienced dentists	−3.16 (− 5.74 to − 0.58)	.016	.256
	Early-career dentists	−2.09 (− 3.64 to − 0.54)	.008	

Models were adjusted for age, sex, and weekly physical activity. Robust standard errors were used for the directional lateral-flexion asymmetry model.

3.6 Associations with NDI and professional exposure

In the primary Spearman analyses, higher NDI scores were associated with lower cervical extension (ρ = −.299, *p* = .022) and greater absolute lateral-flexion asymmetry (ρ = .308, *p* = .018) before correction for multiple testing. Neither association remained statistically significant after FDR correction (*q* = .086 for both). No other cervical movement measure was significantly associated with NDI.

In sensitivity analyses using Pearson correlations, lower extension was associated with higher NDI (*r* = − .348, *p* = .007, FDR-adjusted *q* = .027), and greater absolute lateral-flexion asymmetry was associated

with higher NDI (r = .397, p = .002, q = .015).

Exploratory analyses among dentists identified no significant associations between occupational workload and cervical ROM, movement asymmetry, or NDI (all p > .12).

Figure 2 Cervical movement outcomes across occupational groups. Individual participant values are shown for (A) cervical extension, (B) left lateral flexion, and (C) directional lateral-flexion asymmetry (right minus left). Group means and 95% confidence intervals are presented. Negative directional asymmetry values indicate relatively greater left than right lateral flexion. ED, experienced dentists; ECD, early-career dentists; OW, office workers.

Discussion

The present study identified a distinct cervical movement profile in dentists compared with office workers, rather than a generalized reduction in cervical mobility. Dentists demonstrated reduced cervical extension, greater left lateral flexion, and a different directional pattern of lateral-flexion asymmetry, while most other cervical movements and the absolute magnitude of movement asymmetry did not differ between groups. These differences remained evident after adjustment for age, sex, and physical activity and were already apparent among early-career dentists. Although neck-related disability differed modestly between groups, NDI scores were generally very low, and associations between cervical movement characteristics and disability were not robust after correction for multiple testing. Collectively, these findings suggest that dental practice may be associated with a specific, direction-dependent cervical movement pattern rather than generalized mobility restriction or clinically meaningful neck-related disability.

The reduced cervical extension observed in dentists is broadly consistent with previous evidence of occupation-related alterations in cervical mobility among dental professionals. Zhou et al. [5], in one of the few studies to objectively assess cervical ROM in dentists, reported differences in extension, lateral flexion, and rotation compared with non-dental controls, supporting the premise that the postural demands of dental practice may be reflected in measurable cervical movement characteristics. However, the present findings do not support generalized restriction of cervical mobility. Group differences were limited to extension and left lateral flexion, with no differences in flexion, axial rotation, or right lateral flexion. Moreover, left lateral flexion was greater, rather than reduced, in both dentist groups compared with office workers. This combination of reduced extension and increased mobility in a specific lateral direction may therefore be better characterized as a direction-specific movement profile than as an overall loss of cervical ROM. Notably, these differences were also evident in early-career dentists, who were similar in age to office workers, and persisted after adjustment for potential confounders.

A particularly interesting finding was the direction-specific pattern of lateral-flexion asymmetry. Both dentist groups demonstrated a relative shift toward greater left lateral flexion compared with office workers, whereas absolute lateral-flexion asymmetry did not differ between groups. Thus, dentists were not simply more asymmetric; rather, the direction of their side-to-side mobility differed. This distinction is

potentially important, as previous research in dental professionals has also identified direction-specific cervical mobility patterns. Janczyk et al. [18] reported unequal right- and left-rotation ROM among dental assistants and hygienists and suggested that this directional difference may be related to habitual positioning at the dental unit. Objective kinematic studies further demonstrate that dental treatment involves prolonged and repeated non-neutral and asymmetric positioning of the head, neck, and trunk [14,15], supporting the plausibility of an occupation-related directional movement pattern.

One possible explanation is that repeated exposure to asymmetric working postures may contribute over time to direction-specific adaptations in cervical mobility. Such a mechanism could be consistent with the greater left lateral-flexion ROM and negative right-minus-left asymmetry observed in the dentist groups. However, the direction of working posture is likely to depend on several factors, including operator handedness, position relative to the patient, treatment task, visual strategy, and dental-unit configuration, and cannot be inferred from the present data. Intriguingly, absolute rather than directional lateral-flexion asymmetry showed a modest association with NDI, although this association did not remain significant after FDR correction in the primary Spearman analysis. This raises the possibility that the direction and magnitude of asymmetry represent different phenomena: directional asymmetry may reflect an occupation-related movement pattern, whereas greater absolute asymmetry may be more relevant to disability. Because working position and cervical posture during treatment were not directly measured, however, this proposed mechanism remains hypothesis-generating and requires confirmation through direct ergonomic and kinematic assessment.

Contrary to our initial hypothesis, cervical movement differences did not appear to increase with professional experience. Early-career and experienced dentists demonstrated similar movement patterns, and neither years of dental practice nor cumulative occupational exposure was significantly associated with cervical ROM, asymmetry, or NDI. These findings contrast with epidemiological evidence indicating that longer professional experience is associated with a greater risk of neck pain among dentists [3]. They also differ from the findings of Zhou et al. [5], who reported significant associations between working age and cervical ROM in several directions, including extension, lateral flexion, and right rotation. Differences in sample characteristics, exposure definitions, and analytical approaches may partly account for these discrepancies. Importantly, the absence of an exposure–response relationship in the present study suggests that the observed movement profile may not simply reflect progressive accumulation of occupational exposure. An alternative possibility is that occupation-related neuromuscular and movement adaptations develop relatively early after the onset of clinical dental practice and subsequently stabilize rather than progressing linearly with years of exposure. Supporting this possibility, Almeida et al. [6] demonstrated changes in cervical muscle activation patterns in dental students after only their first semester of clinical training. The cross-sectional design of the present study, however, precludes conclusions regarding when the observed differences developed or whether they represent true occupational adaptations.

Despite the observed movement differences, neck-related disability was generally low. Although NDI scores differed significantly between groups, with experienced dentists reporting higher scores than

office workers, the absolute level of disability was minimal: the median NDI score was 2, nearly one-third of participants reported no disability, and 78% scored within the 0–4 range. The statistically significant between-group difference should therefore be interpreted cautiously and may have limited clinical relevance. Associations between cervical movement characteristics and NDI were also modest. Reduced extension and greater absolute lateral-flexion asymmetry were associated with higher NDI scores in the primary Spearman analyses, but neither association remained significant after correction for multiple comparisons. Although both associations persisted in the Pearson sensitivity analysis, this inconsistency indicates that the relationship between cervical movement and self-reported disability was not robust. This limited correspondence between cervical mobility and self-reported disability is consistent with previous literature suggesting that the relationship between cervical ROM and NDI is generally weak or inconsistently demonstrated [19]. Notably, directional lateral-flexion asymmetry, which differentiated dentists from office workers, was not associated with NDI. Overall, the cervical movement pattern observed in dentists therefore does not appear to be accompanied by substantial neck-related disability. Whether these characteristics represent relatively benign occupational adaptations or are associated with the future development of neck symptoms requires longitudinal investigation.

From a clinical perspective, these findings suggest that assessment of musculoskeletal health in dental professionals may benefit from considering cervical movement characteristics in addition to pain and self-reported disability. The presence of measurable differences even among early-career dentists may be particularly relevant to ergonomic assessment, where attention is typically directed toward reducing prolonged or non-neutral working postures [2,16,17]. However, greater mobility or directional asymmetry should not in itself be interpreted as dysfunction, particularly given the low NDI scores in the present sample. Rather, the findings support consideration of individual cervical movement patterns in relation to habitual working posture. Prospective studies are needed to determine whether these characteristics identify dentists at increased risk of developing neck symptoms and whether ergonomic or exercise-based interventions can modify these patterns and improve clinical outcomes.

Several strengths and limitations should be considered. Strengths include the use of standardized objective cervical ROM measurements, the inclusion of both early-career and experienced dentists together with an occupationally comparable office-worker group, and the distinction between directional and absolute asymmetry. Multivariable analyses accounting for age, sex, and physical activity further strengthened the interpretation of the principal between-group findings. Nevertheless, the cross-sectional design precludes causal or temporal conclusions, and the relatively small sample may have limited the detection of subtle between-group differences and associations with occupational exposure. Experienced dentists were older than the other groups; although the principal findings persisted after adjustment for age, residual confounding cannot be excluded. The low NDI scores also produced a restricted range and potential floor effect, which may have reduced the ability to identify associations with disability. Cumulative occupational exposure was based on self-reported working hours, weeks per year, and years of practice, while potentially relevant ergonomic factors—including habitual operator position, dental-unit configuration, use of direct versus indirect vision, and cervical posture during treatment—were not directly assessed. These limitations are particularly relevant to the direction-specific

lateral-flexion findings and prevent determination of whether the observed pattern reflects adaptation to habitual working posture. Finally, cervical ROM was assessed using smartphone-based applications by a single trained examiner rather than laboratory-based three-dimensional motion analysis. Although smartphone-based cervical ROM assessment has demonstrated acceptable reliability and validity [10–13], future studies incorporating direct kinematic monitoring during dental procedures could more directly examine the relationship between occupational posture and cervical movement characteristics.

Conclusions

Dentists demonstrated a distinct cervical movement profile characterized by reduced extension, greater left lateral flexion, and direction-specific lateral-flexion asymmetry rather than generalized restriction of cervical mobility. These differences were evident in both early-career and experienced dentists and persisted after adjustment for age, sex, and physical activity, while no clear association with years of professional experience or occupational workload was identified. Neck-related disability was generally minimal, and its associations with cervical movement characteristics were modest and not robust across analyses. These findings suggest that occupation-related cervical movement differences may be present early in dental practice without substantial functional disability. Longitudinal studies incorporating direct assessment of working posture and cervical kinematics are needed to determine whether these patterns represent occupational adaptations and whether they are associated with the subsequent development of neck-related symptoms or disability.

Declarations

Funding

The authors received no funding for this study.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author contributions

T.G. conceived and designed the study, supervised the study methodology and data collection, contributed to data interpretation, and drafted the manuscript. N.Z. recruited participants, performed the clinical assessments and data collection, and contributed to manuscript preparation. P.K. critically reviewed and revised the manuscript and contributed to improving its scientific content and clarity. A.E.-P. contributed to study conception and design, supervised the study, contributed to interpretation of the results, and critically revised the manuscript for important intellectual content. All authors reviewed and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Ethics approval

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee of the Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University (approval No. 0008846-3).

Consent to participate

Written informed consent was obtained from all participants prior to participation

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Figures

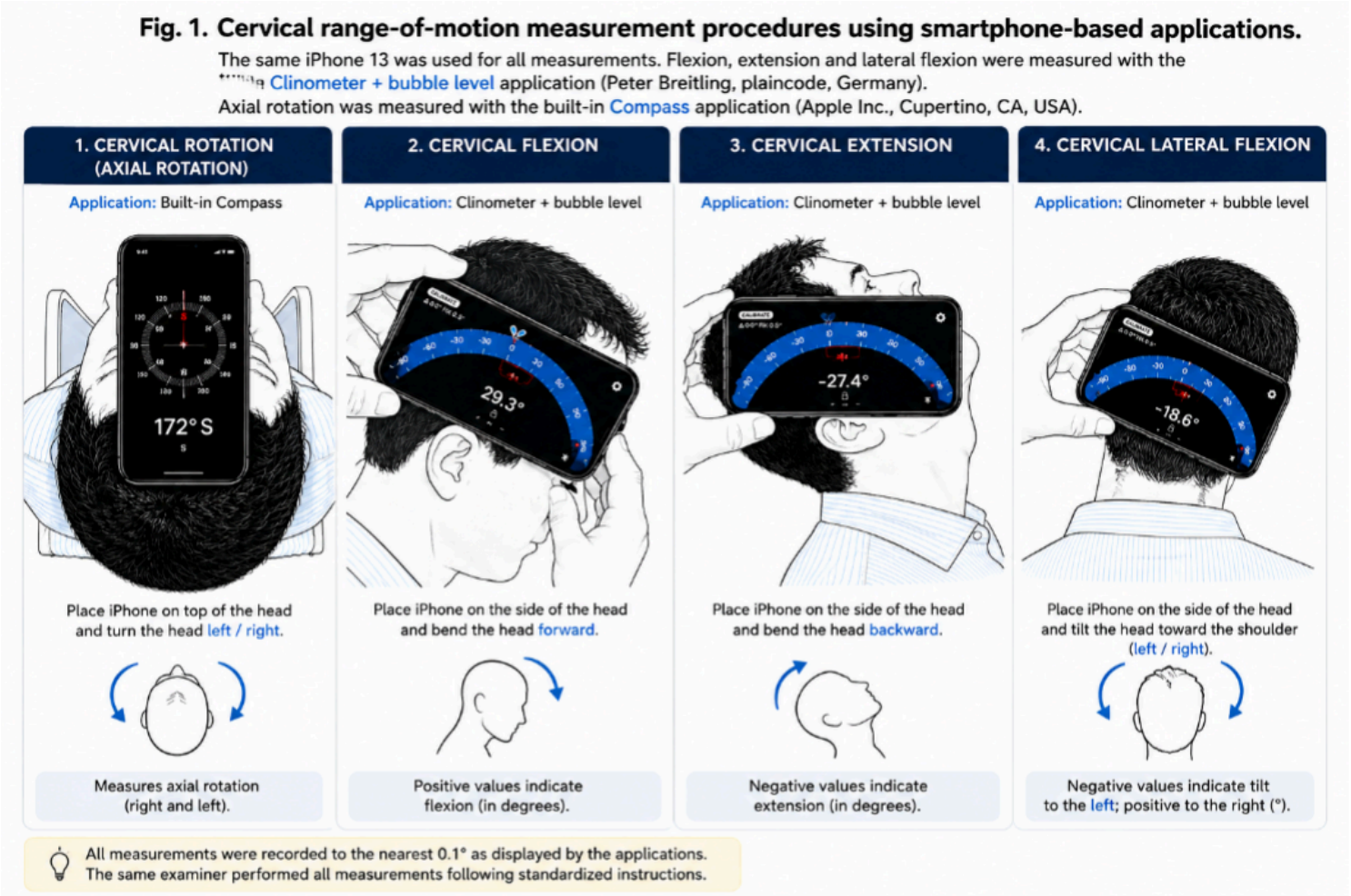


Figure 1

See image above for figure legend.

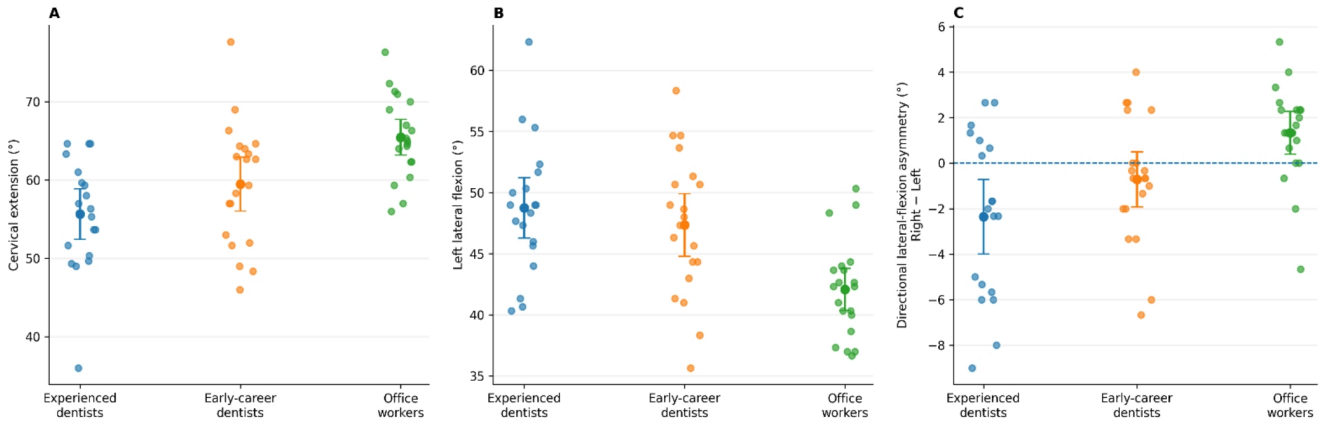


Figure 2

Cervical movement outcomes across occupational groups

Fig. 2 Cervical movement outcomes across occupational groups. Individual participant values are shown for (A) cervical extension, (B) left lateral flexion, and (C) directional lateral-flexion asymmetry (right minus left). Group means and 95% confidence intervals are presented. Negative directional asymmetry values indicate relatively greater left than right lateral flexion. ED, experienced dentists; ECD, early-career dentists; OW, office workers.