

Longitudinal Evaluation of Occupational Postural Risk, Ergonomic Adaptation, and Cervico-Musculoskeletal Symptoms among Oral Healthcare Clinicians

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Abstract

Occupational oral healthcare practice frequently requires prolonged static posture, repetitive upper-extremity movements, sustained cervical flexion, and continuous visual concentration within restricted operative fields. These occupational demands may contribute to cumulative cervico-musculoskeletal strain and work-related musculoskeletal disorders among clinicians. This longitudinal observational study evaluated occupational postural risk, ergonomic adaptation, and cervico-musculoskeletal symptom patterns among oral healthcare clinicians over a 12-month follow-up period.

A total of 60 oral healthcare clinicians were evaluated using the Rapid Entire Body Assessment (REBA) tool and the standardized Nordic Musculoskeletal Questionnaire at baseline, six months, and twelve months. Ergonomic practice adherence was additionally assessed using a structured observational checklist. Longitudinal changes in ergonomic risk exposure and symptom prevalence were analyzed using repeated-measures analysis of variance, correlation analysis, and multivariate regression modeling.

Mean REBA scores demonstrated a significant progressive reduction from 6.8 ± 1.1 at baseline to 5.7 ± 0.9 at twelve months ($p < 0.001$). The cervical region, shoulders, and lower back were the most frequently affected anatomical sites. Ergonomic practice adherence showed a significant negative correlation with symptom severity ($r = -0.46$, $p = 0.003$). Higher baseline ergonomic risk and longer clinical experience were significantly associated with persistent symptoms.

Overall, improved ergonomic adaptation was associated with reduced occupational postural risk and lower cervico-musculoskeletal symptom burden during follow-up.

Keywords: occupational ergonomics; postural risk; cervico-musculoskeletal disorders; ergonomic adaptation; oral healthcare clinicians.

1. Introduction

The practice of oral healthcare routinely requires clinicians to perform precision-based clinical procedures within restricted operative environments while maintaining prolonged static posture and continuous visual concentration. Routine dental procedures frequently involve sustained cervical flexion, repetitive upper-extremity movements, forward head posture, shoulder elevation, and prolonged seated positioning. These occupational demands may progressively increase biomechanical stress involving the cervical spine, thoracic musculature, shoulders, and lumbar region, thereby contributing to the development of cervico-musculoskeletal disorders among oral healthcare professionals [1,2].

Work-related musculoskeletal disorders are recognized as one of the most prevalent occupational health concerns among healthcare professionals exposed to repetitive movements and sustained posture during clinical activity [3]. In oral healthcare settings, clinicians commonly work within limited intraoral operative fields that require prolonged muscular stabilization and repetitive fine motor activity. Continuous exposure to such unfavorable ergonomic conditions may result in muscular fatigue, ligamentous strain, spinal imbalance, reduced functional efficiency, and chronic pain involving the neck, shoulders, upper back, and lower back regions [4,5].

The cervical and lumbar regions are particularly vulnerable to occupational biomechanical loading during oral healthcare procedures. Sustained neck flexion and prolonged seated posture may alter normal spinal alignment and increase static muscular activation in the cervical and paraspinal musculature. Similarly, repetitive shoulder abduction and trunk inclination during patient-care procedures may contribute to progressive shoulder dysfunction and lumbar discomfort [6]. Over time, these cumulative occupational stresses may negatively influence clinical efficiency, concentration, procedural precision, and professional well-being among oral healthcare clinicians.

Several epidemiological studies have reported a high prevalence of neck pain, shoulder discomfort, and lower back symptoms among dentists, orthodontists, dental hygienists, and other oral healthcare providers [7–9]. Persistent occupational musculoskeletal symptoms may adversely affect clinical productivity and long-term professional sustainability and may contribute to reduced work performance, temporary absence from clinical duties, and occupational burnout [10]. Consequently, occupational ergonomics has become an increasingly important component of preventive healthcare strategies in modern dental practice.

Ergonomics in oral healthcare primarily focuses on optimizing operator posture, minimizing repetitive biomechanical strain, improving working position, and reducing prolonged static muscular activity during clinical procedures [11]. Appropriate ergonomic adaptation, including neutral spinal alignment, proper patient positioning, ergonomic instrument accessibility, use of indirect vision techniques, and incorporation of periodic micro-breaks, may significantly reduce occupational postural loading and musculoskeletal stress among clinicians [12,13]. However, despite increasing awareness regarding ergonomic principles, ergonomic compliance during routine clinical practice remains inconsistent, particularly in busy healthcare environments where habitual posture patterns are frequently maintained for prolonged periods [14].

Most currently available evidence regarding occupational musculoskeletal disorders among oral healthcare professionals is primarily derived from cross-sectional investigations that evaluate symptom prevalence at a single time point [15,16]. Although such studies provide important epidemiological information, they inadequately explain the longitudinal progression of occupational postural exposure, ergonomic adaptation, and cervico-musculoskeletal symptom burden over time. Considering the cumulative and progressive nature of occupational musculoskeletal strain, longitudinal evaluations are essential for understanding the temporal relationship between ergonomic exposure and musculoskeletal health outcomes among clinicians [17].

Validated assessment systems such as the Rapid Entire Body Assessment (REBA) tool and the Nordic Musculoskeletal Questionnaire provide standardized approaches for evaluating occupational postural risk and musculoskeletal symptom distribution in healthcare environments involving repetitive precision-based activity [18,19]. However, longitudinal investigations

integrating ergonomic risk assessment and cervico-musculoskeletal symptom evaluation among oral healthcare clinicians remain limited in the available literature.

Therefore, the present longitudinal observational study aimed to evaluate occupational postural risk, ergonomic adaptation, and cervico-musculoskeletal symptom patterns among oral healthcare clinicians during a 12-month follow-up period. Additionally, the study investigated the relationship between ergonomic practice adherence, occupational postural exposure, and musculoskeletal symptom severity during routine oral healthcare practice.

2. Review of Literature

2.1 Occupational Postural Risk in Oral Healthcare Practice

Occupational postural risk is considered a major contributing factor to musculoskeletal disorders among oral healthcare professionals. Clinical dental procedures frequently require prolonged seated posture, sustained cervical flexion, repetitive hand movements, and continuous visual concentration within restricted operative fields. These occupational characteristics may significantly increase static muscular loading and biomechanical stress involving the cervical spine, shoulders, thoracic musculature, and lumbar region [20].

Previous ergonomic investigations have demonstrated that oral healthcare clinicians commonly adopt awkward working postures during restorative, orthodontic, surgical, and preventive procedures [21]. Prolonged maintenance of non-neutral spinal alignment may progressively contribute to muscular fatigue, postural imbalance, and chronic cervico-musculoskeletal dysfunction [22]. The Rapid Entire Body Assessment system has been widely utilized for evaluating occupational ergonomic exposure because it provides a standardized assessment of whole-body postural loading associated with repetitive and static occupational activities [18].

2.2 Cervico-Musculoskeletal Disorders among Oral Healthcare Clinicians

Cervico-musculoskeletal disorders represent one of the most frequently reported occupational health problems among oral healthcare professionals. The cervical region, shoulders, and lower back are consistently identified as the most commonly affected anatomical regions because these

areas are continuously exposed to sustained muscular activity and repetitive biomechanical strain during clinical procedures [23].

Several studies have reported high prevalence rates of neck pain, shoulder discomfort, and lumbar symptoms among dentists and orthodontists [24,25]. Repetitive occupational exposure may gradually result in muscular imbalance, soft-tissue strain, reduced range of motion, and chronic pain symptoms that may adversely affect professional efficiency and quality of life [26]. In severe cases, prolonged musculoskeletal dysfunction may contribute to psychological stress, reduced work productivity, and occupational burnout among clinicians [27].

2.3 Ergonomic Adaptation and Preventive Occupational Strategies

Ergonomic adaptation plays an important role in reducing occupational biomechanical strain during oral healthcare practice. Appropriate ergonomic interventions may include neutral operator posture, optimized patient-chair positioning, ergonomic instrument accessibility, indirect vision techniques, and incorporation of scheduled recovery intervals during prolonged clinical procedures [28].

Previous ergonomic intervention studies have demonstrated that ergonomic awareness and posture correction strategies may significantly reduce musculoskeletal symptom burden and occupational postural risk among healthcare professionals exposed to repetitive static activity [29]. Educational ergonomic training programs have also shown positive effects on postural behavior and occupational health outcomes among dental students and practicing clinicians [30]. However, despite increasing awareness regarding occupational ergonomics, long-term ergonomic compliance and adaptation remain inconsistent in routine oral healthcare settings.

2.4 Research Gap

Although several studies have evaluated musculoskeletal disorders among oral healthcare professionals, most available evidence remains cross-sectional in design and primarily focuses on symptom prevalence rather than longitudinal progression [31]. Limited investigations have simultaneously evaluated occupational postural exposure, ergonomic adaptation, and cervico-

musculoskeletal symptom patterns over an extended follow-up period using standardized ergonomic assessment tools.

Furthermore, the relationship between ergonomic practice adherence and longitudinal changes in occupational postural risk remains insufficiently explored among oral healthcare clinicians. Considering the cumulative nature of occupational biomechanical strain, longitudinal assessment is essential for understanding the progressive effects of ergonomic exposure and adaptive occupational behavior on musculoskeletal health outcomes.

Therefore, the present study was designed to longitudinally evaluate occupational postural risk, ergonomic adaptation, and cervico-musculoskeletal symptom patterns among oral healthcare clinicians using validated ergonomic and musculoskeletal assessment methods.

3. Materials and Methods

3.1 Study Design and Setting

This longitudinal observational study was conducted over a 12-month follow-up period to evaluate occupational postural risk, ergonomic adaptation, and cervico-musculoskeletal symptom patterns among oral healthcare clinicians engaged in routine clinical practice. The study was performed in institutional dental clinics and private oral healthcare settings in Central India.

Routine oral healthcare procedures commonly require prolonged static posture, sustained cervical flexion, repetitive upper-extremity movements, and continuous visual concentration within restricted operative fields. These occupational demands may progressively contribute to cumulative biomechanical loading involving the cervical spine, shoulders, thoracic musculature, and lumbar region. Therefore, a longitudinal observational design was adopted to evaluate temporal changes in occupational postural exposure and musculoskeletal symptom burden among clinicians during routine patient-care procedures.

3.2 Ethical Approval

The study protocol was reviewed and approved by the Institutional Ethics Committee of Mansarovar Dental College, Hospital and Research Centre, Bhopal, India (IEC No. 34IEC/2024/DENT/031). All study procedures were performed in accordance with the ethical

principles outlined in the Declaration of Helsinki for research involving human participants. Written informed consent was obtained from all participants prior to enrollment.

3.3 Study Population and Sampling

A total of 60 oral healthcare clinicians actively involved in routine clinical practice were enrolled in the study using purposive sampling methodology. The study population included clinicians performing preventive, diagnostic, restorative, orthodontic, and routine oral healthcare procedures.

To improve representation of occupational exposure characteristics, participants were evaluated across different clinical practice settings and professional experience categories. Demographic and occupational characteristics, including age, gender, primary clinical practice setting, and years of professional experience, were recorded at baseline assessment.

3.4 Inclusion and Exclusion Criteria

Clinicians were considered eligible for participation if they:

- were between 25 and 55 years of age;
- had a minimum of two years of continuous clinical experience;
- were actively engaged in clinical practice for at least 20 hours per week; and
- agreed to participate in all scheduled follow-up assessments.

Participants were excluded if they had:

- a previously diagnosed systemic musculoskeletal or neurological disorder;
- a history of recent orthopedic trauma or surgery;
- ongoing pregnancy during the study period; or
- received physiotherapy, rehabilitation therapy, or musculoskeletal pharmacological treatment within the previous six months.

3.5 Follow-Up Schedule

All participants were evaluated at three predefined assessment intervals:

- baseline assessment (T0),
- six-month follow-up assessment (T1), and
- twelve-month follow-up assessment (T2).

This longitudinal follow-up design enabled evaluation of both early and progressive changes in occupational postural exposure, ergonomic adaptation, and cervico-musculoskeletal symptom patterns over time.

3.6 Assessment of Cervico-Musculoskeletal Symptoms

Cervico-musculoskeletal symptoms were evaluated using the standardized Nordic Musculoskeletal Questionnaire (NMQ), which is a validated epidemiological assessment tool commonly utilized in occupational and healthcare ergonomic research.

The questionnaire records the presence and anatomical distribution of musculoskeletal symptoms involving multiple body regions during the preceding twelve months and seven days. In the present study, particular emphasis was placed on evaluation of the cervical region, shoulders, upper back, and lower back because these anatomical areas are frequently exposed to occupational biomechanical strain during oral healthcare procedures.

Participants completed the questionnaire under investigator supervision to maintain consistency of data recording and minimize reporting variability.

3.7 Occupational Postural Risk Assessment

Occupational postural risk was evaluated using the Rapid Entire Body Assessment (REBA) tool, a validated ergonomic assessment system developed to quantify whole-body postural loading associated with occupational activities involving static posture, repetitive movement, and awkward body positioning.

Clinical working posture was assessed during routine patient-care procedures under natural clinical operating conditions. Postural evaluation included assessment of:

- neck position,
- trunk flexion,
- upper and lower limb posture,
- wrist alignment,
- static muscular activity,
- movement repetition, and
- occupational postural loading.

Each participant received a final REBA score corresponding to the degree of occupational ergonomic risk exposure. Based on standard REBA classification criteria, ergonomic risk levels were categorized as negligible, low, moderate, high, or very high occupational risk exposure.

3.8 Ergonomic Practice Assessment

Ergonomic practice adherence was evaluated using a structured ergonomic observational checklist developed from previously reported ergonomic recommendations for oral healthcare professionals.

The checklist included assessment of:

- operator seating posture,

- patient-chair positioning,
- instrument accessibility,
- indirect vision utilization,
- posture correction frequency,
- ergonomic equipment utilization, and
- incorporation of micro-breaks during clinical procedures.

Ergonomic compliance scores were recorded during each assessment interval to evaluate longitudinal changes in ergonomic behavior and adaptive occupational practices.

3.9 Examiner Calibration

Prior to data collection, examiner calibration sessions were conducted to standardize REBA scoring procedures and ergonomic observations. Ten clinicians not included in the final study sample were evaluated twice at two-week intervals to assess intra-examiner reliability and consistency of ergonomic assessment measurements.

3.10 Statistical Analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) software version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for demographic characteristics, occupational postural risk scores, ergonomic practice variables, and cervico-musculoskeletal symptom prevalence.

Normality of data distribution was evaluated using the Shapiro–Wilk test. Longitudinal changes in REBA scores and symptom prevalence across the three assessment intervals were analyzed using repeated-measures analysis of variance (ANOVA).

Pearson’s correlation analysis was performed to evaluate the relationship between ergonomic practice adherence and cervico-musculoskeletal symptom severity. Multivariate regression analysis was additionally conducted to identify predictors associated with persistent cervico-musculoskeletal symptoms during follow-up.

Statistical significance was established at $p < 0.05$ throughout the analysis.

4. Results

A total of 60 oral healthcare clinicians completed all baseline and follow-up assessments, resulting in complete longitudinal follow-up compliance throughout the 12-month observation period. The demographic and professional characteristics of the study participants are summarized in Table 1. The mean age of the participants was 34.5 ± 6.2 years, whereas the mean duration of clinical experience was 8.4 ± 3.5 years. Most clinicians were engaged in private oral healthcare practice settings and routinely reported prolonged seated clinical activity during patient-care procedures.

4.1 Longitudinal Changes in Occupational Postural Risk

Occupational postural risk scores demonstrated a progressive reduction throughout the longitudinal follow-up period. At baseline assessment, the mean REBA score was 6.8 ± 1.1 , indicating moderate occupational ergonomic risk exposure. The mean REBA score progressively decreased to 6.2 ± 1.0 at the six-month follow-up assessment and further declined to 5.7 ± 0.9 at the twelve-month evaluation. Repeated-measures analysis of variance demonstrated a statistically significant reduction in occupational postural risk scores during follow-up ($F = 18.24$, $p < 0.001$).

The longitudinal decline in REBA scores indicated gradual improvement in occupational posture and ergonomic adaptation among clinicians during routine clinical practice. Participants who demonstrated increased ergonomic awareness and more frequent posture correction generally exhibited comparatively lower occupational postural risk scores during later assessment intervals.

Additionally, longitudinal changes in ergonomic risk classification were observed during the study period. At baseline, most clinicians were categorized within moderate and high ergonomic risk groups. However, progressive reductions in high-risk ergonomic exposure were identified during follow-up, whereas the proportion of clinicians categorized within lower-risk groups gradually increased at the final assessment interval.

4.2 Distribution of Cervico-Musculoskeletal Symptoms

The prevalence and anatomical distribution of cervico-musculoskeletal symptoms at different assessment intervals are presented in Table 3. The lower back, cervical region, and shoulders were the most frequently affected anatomical regions throughout the study period.

At baseline assessment, lower back symptoms were reported by approximately 52% of participants, followed by cervical symptoms in 48% and shoulder symptoms in 45% of clinicians. Progressive reductions in musculoskeletal symptom prevalence were observed during longitudinal follow-up. At the twelve-month assessment, lower back symptom prevalence decreased to 38%, whereas cervical and shoulder symptoms declined to 35% and 30%, respectively.

The temporal reduction in symptom prevalence was most evident in anatomical regions commonly exposed to prolonged occupational biomechanical loading during oral healthcare procedures, particularly the cervical spine, lumbar region, and shoulders. In contrast, upper back and wrist-related symptoms demonstrated comparatively smaller longitudinal changes during follow-up.

4.3 Ergonomic Practice Adherence and Symptom Severity

Progressive improvements in ergonomic practice adherence were observed throughout the study period. Increased awareness regarding operator positioning, patient-chair adjustment, use of indirect vision techniques, and incorporation of periodic micro-breaks during clinical procedures was more frequently reported during later follow-up assessments.

Pearson's correlation analysis demonstrated a statistically significant moderate negative correlation between ergonomic practice adherence and cervico-musculoskeletal symptom severity

($r = -0.46$, $p = 0.003$). These findings indicated that clinicians with greater ergonomic compliance generally experienced lower musculoskeletal symptom burden during follow-up.

The correlation analysis further suggested that progressive ergonomic adaptation may contribute to reduction of occupational biomechanical strain and improvement in musculoskeletal health outcomes among oral healthcare clinicians exposed to prolonged static posture and repetitive clinical activity.

4.4 Predictors of Persistent Cervico-Musculoskeletal Symptoms

Multivariate regression analysis identified baseline occupational postural risk scores and duration of clinical experience as significant predictors of persistent cervico-musculoskeletal symptoms during the follow-up period. Higher baseline REBA scores demonstrated a statistically significant positive association with persistent musculoskeletal discomfort during longitudinal assessment ($\beta = 0.38$, $p = 0.004$). Similarly, longer professional clinical experience was significantly associated with increased persistence of musculoskeletal symptoms ($\beta = 0.29$, $p = 0.021$).

In contrast, age greater than 35 years and gender did not demonstrate statistically significant associations with persistent symptom burden during follow-up.

4.5 Overall Longitudinal Findings

Overall, the present longitudinal evaluation demonstrated that occupational postural risk and cervico-musculoskeletal symptoms were highly prevalent among oral healthcare clinicians engaged in routine clinical practice. However, progressive ergonomic adaptation and increased ergonomic awareness during the follow-up period were associated with significant reductions in occupational postural risk exposure and musculoskeletal symptom severity.

The longitudinal findings additionally indicated that clinicians with higher baseline ergonomic risk exposure and prolonged professional experience may remain more vulnerable to persistent occupational musculoskeletal dysfunction. These observations emphasize the importance of preventive ergonomic strategies and periodic occupational postural assessment in oral healthcare environments.

5. Discussion

The present longitudinal observational study evaluated occupational postural risk, ergonomic adaptation, and cervico-musculoskeletal symptom patterns among oral healthcare clinicians during a 12-month follow-up period. The findings demonstrated that occupational postural risk and musculoskeletal symptoms were highly prevalent among clinicians engaged in routine oral healthcare practice. However, progressive ergonomic adaptation and increased ergonomic awareness during follow-up were associated with significant reductions in occupational postural risk exposure and cervico-musculoskeletal symptom burden.

Oral healthcare professionals are routinely exposed to occupational conditions requiring prolonged static posture, sustained cervical flexion, repetitive upper-extremity activity, and continuous visual concentration within restricted operative fields. These occupational demands may substantially increase biomechanical loading involving the cervical spine, shoulders, thoracic musculature, and lumbar region [1–3]. In the present study, the cervical region, shoulders, and lower back were identified as the most frequently affected anatomical regions throughout the observation period. These findings are consistent with previous investigations reporting high prevalence rates of neck pain, shoulder discomfort, and lumbar symptoms among dentists, orthodontists, and other oral healthcare providers exposed to repetitive precision-oriented clinical activity [4–6].

The longitudinal reduction in REBA scores observed during follow-up suggests gradual improvement in occupational posture and ergonomic behavior among clinicians. Baseline REBA scores in the present study indicated moderate occupational ergonomic risk exposure, whereas progressive reductions in ergonomic risk scores were observed during subsequent follow-up assessments. These findings support previous ergonomic investigations demonstrating that increased ergonomic awareness and postural correction strategies may reduce occupational biomechanical strain during clinical procedures [7,8].

The reduction in high-risk ergonomic classifications identified during follow-up further emphasizes the potential influence of adaptive ergonomic behavior on occupational musculoskeletal health outcomes. Clinicians who reported greater ergonomic awareness and more frequent posture correction generally demonstrated lower occupational postural risk scores during later assessments. This observation suggests that even modest ergonomic modifications during routine clinical activity may positively influence occupational postural exposure over time.

The present study additionally demonstrated progressive reductions in cervico-musculoskeletal symptom prevalence during follow-up, particularly involving the cervical region, shoulders, and lower back. These anatomical regions are continuously exposed to sustained muscular activation and repetitive biomechanical loading during oral healthcare procedures. Prolonged cervical flexion, repetitive shoulder abduction, static seated posture, and trunk inclination may collectively contribute to cumulative musculoskeletal strain involving the cervical and lumbar regions [9,10].

The observed reduction in symptom burden during longitudinal follow-up may be associated with progressive ergonomic adaptation among clinicians. Participants demonstrating improved ergonomic compliance, including optimized patient-chair positioning, use of indirect vision techniques, periodic posture correction, and incorporation of micro-breaks during clinical procedures, generally exhibited reduced musculoskeletal symptom severity. Similar findings have been reported in ergonomic intervention studies evaluating healthcare professionals exposed to prolonged static occupational posture [11,12].

The statistically significant moderate negative correlation identified between ergonomic practice adherence and cervico-musculoskeletal symptom severity further highlights the clinical importance of occupational ergonomic behavior. The findings suggest that clinicians demonstrating greater ergonomic compliance experienced lower occupational musculoskeletal burden during follow-up. This relationship is clinically relevant because many ergonomic modifications applicable to oral healthcare practice are relatively simple, practical, and economically feasible. Appropriate operator positioning, maintenance of neutral cervical alignment, ergonomic instrument accessibility, and scheduled recovery intervals may collectively reduce repetitive biomechanical strain and muscular fatigue during prolonged clinical activity [13,14].

The present findings additionally demonstrated that higher baseline occupational postural risk scores and longer duration of professional clinical experience were significantly associated with persistent musculoskeletal symptoms during follow-up. These observations may reflect the cumulative nature of occupational biomechanical exposure in oral healthcare environments. Repetitive occupational loading over prolonged periods may progressively contribute to muscular imbalance, repetitive microtrauma, ligamentous strain, and adaptive postural alterations, thereby increasing susceptibility to chronic cervico-musculoskeletal dysfunction [15,16].

Interestingly, age greater than 35 years and gender did not demonstrate statistically significant associations with persistent symptom burden in the present study. These findings suggest that occupational ergonomic exposure and cumulative biomechanical loading may play a more substantial role in musculoskeletal symptom progression than demographic characteristics alone.

Similar observations have been reported in previous occupational ergonomic studies involving dental and healthcare professionals [17].

The lower back remained the most prevalent symptomatic anatomical region throughout the study period. Sustained seated posture, inadequate lumbar support, repetitive trunk inclination, and prolonged static muscular activity during patient-care procedures may significantly contribute to lumbar biomechanical loading [18]. Similarly, continuous cervical flexion and shoulder elevation during precision-based oral healthcare procedures likely explain the high prevalence of cervical and shoulder symptoms observed among clinicians in the present investigation.

Unlike cross-sectional investigations that primarily provide symptom prevalence estimates, the present longitudinal design enabled evaluation of temporal changes in occupational postural exposure and cervico-musculoskeletal symptom progression over an extended follow-up period. The repeated assessment methodology improved understanding of ergonomic adaptation and occupational musculoskeletal evolution during routine clinical practice. Additionally, the use of validated assessment systems, including the Rapid Entire Body Assessment tool and Nordic Musculoskeletal Questionnaire, strengthened methodological reliability and enabled standardized evaluation of ergonomic exposure and musculoskeletal health outcomes [19,20].

Nevertheless, certain limitations should be considered while interpreting the findings of the present study. The sample size was relatively limited and restricted to selected oral healthcare settings, which may influence generalizability of the findings to broader professional populations. Furthermore, musculoskeletal symptoms were assessed using self-reported questionnaires, which may introduce reporting variability. Although ergonomic adaptation improved progressively during follow-up, the study did not include a structured ergonomic intervention program or objective biomechanical motion analysis.

Despite these limitations, the present study provides clinically relevant longitudinal evidence regarding occupational postural risk and cervico-musculoskeletal symptom progression among oral healthcare clinicians. The findings emphasize the importance of early ergonomic awareness, periodic occupational postural assessment, and integration of preventive ergonomic strategies into routine oral healthcare practice. Such measures may contribute to reduction of occupational

musculoskeletal burden, improvement of clinician well-being, and preservation of long-term professional performance in oral healthcare environments.

6. Conclusion

Within the limitations of the present longitudinal observational study, occupational postural risk and cervico-musculoskeletal symptom burden were found to be highly prevalent among oral healthcare clinicians engaged in routine clinical practice. The cervical region, shoulders, and lower back were identified as the most frequently affected anatomical regions associated with sustained static posture, repetitive upper-extremity activity, and prolonged occupational biomechanical loading during oral healthcare procedures.

The longitudinal findings demonstrated a progressive reduction in occupational postural risk scores and musculoskeletal symptom prevalence during the 12-month follow-up period. Improved ergonomic adaptation and increased ergonomic awareness were associated with reduced occupational postural exposure and lower cervico-musculoskeletal symptom severity among clinicians. Additionally, ergonomic practice adherence demonstrated a significant inverse relationship with symptom burden, emphasizing the importance of preventive ergonomic behavior in routine oral healthcare settings.

Higher baseline ergonomic risk exposure and longer duration of professional clinical experience were significantly associated with persistent musculoskeletal symptoms, indicating the cumulative nature of occupational biomechanical strain in oral healthcare practice. These findings further suggest that prolonged exposure to unfavorable working posture may progressively contribute to chronic occupational musculoskeletal dysfunction if preventive ergonomic measures are not adequately implemented.

Overall, the present study highlights the clinical importance of integrating ergonomic education, periodic postural assessment, and preventive occupational health strategies into routine oral healthcare practice and professional training programs. Early identification of high-risk occupational posture and sustained ergonomic adaptation may help reduce the occupational musculoskeletal burden, improve clinician well-being, and support long-term professional sustainability among oral healthcare providers.

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Tables

Table 1. Demographic and Professional Characteristics of the Study Participants (n = 60)

Variable	Mean $\pm$ SD / n (%)
Age (years)	34.5 $\pm$ 6.2
Gender	
• Male	35 (58.3%)
• Female	25 (41.7%)
Primary practice setting	
• Private oral healthcare practice	38 (63.3%)
• Institutional clinical setting	22 (36.7%)
Clinical experience (years)	8.4 $\pm$ 3.5

Table 2. Longitudinal Changes in Occupational Postural Risk Scores (REBA) Across Follow-up Period

Time point	Mean REBA score $\pm$ SD
Baseline (T0)	6.8 $\pm$ 1.1
6 months (T1)	6.2 $\pm$ 1.0
12 months (T2)	5.7 $\pm$ 0.9

Statistical test: Repeated-measures ANOVA, **F-value:** 18.24, **p-value:** < 0.001

Table 3. Prevalence of Cervico-Musculoskeletal Symptoms at Different Follow-up Intervals

Anatomical region	Baseline (T0)	6 months (T1)	12 months (T2)
Lower back	52%	—	38%
Neck	48%	—	35%
Shoulders	45%	—	30%

Table 4. Correlation between Ergonomic Practice Adherence and Cervico-Musculoskeletal Symptom Severity

Variables analyzed	Correlation coefficient (r)	p-value
Ergonomic practice score vs. symptom severity	-0.46	0.003

Table 5. Multivariate Regression Analysis of Predictors of Persistent or Worsening Cervico-Musculoskeletal Symptoms

Predictor variable	Standardized beta (β)	p-value
Baseline REBA score	0.38	0.004
Years of clinical experience	0.29	0.021
Gender	Not significant	—
Age (>35 years)	Not significant	—





