Trapezius Muscle Activity in using Ordinary and Ergonomically Designed Dentistry Chairs

O Haddad¹, MA Sanjari², A Amirfazli³, R Narimani³, M Parnianpour³,⁴

Abstract

Background: Most dentists complain of musculoskeletal disorders which can be caused by prolonged static posture, lack of suitable rest and other physical and psychological problems.

Objective: We evaluated a chair with a new ergonomic design which incorporated forward leaning chest and arm supports.

Methods: The chair was evaluated in the laboratory during task simulation and EMG analysis on 12 students and subjectively assessed by 30 professional dentists using an 18-item questionnaire. EMG activity of right and left trapezius muscles for 12 male students with no musculoskeletal disorders was measured while simulating common tasks like working on the teeth of the lower jaw.

Results: Normalized EMG data showed significant reduction (p<0.05) in all EMG recordings of the trapezius muscle. Dentists also unanimously preferred the ergonomically designed chair.

Conclusion: Such ergonomically designed chairs should be introduced as early as possible in student training before bad postural habits are acquired.

Keywords: Dentist; Electromyography; Human engineering; Musculoskeletal disorders; Trapezius

Introduction

In recent years, consideration of musculoskeletal disorders (MSDs) in dental practice has increased noticeably due to an increase in the number of reported MSDS. Many studies have characterized different parameters of pain in dentists.¹⁻³ For example, the prevalence of back pain in dentists has been reported to range from 36% to 72% of the sample investigated.¹ Although the numbers vary in the literature, many studies have observed that dental professionals are at high risk for developing work-related MSDS.⁴⁻⁵ Areas most at risk appear to be the neck, shoulder and the back.⁶⁻¹¹

Work-related MSDS are multifactorial, however occupational factors such as workstation design, work technique, posture and tools have significant impact on developing MSDS in dentistry.¹² The following risk factors lead to upper extremity pain: extended workdays, awkward and prolonged static postures, unsupported sitting, inadequately designed workstations, poor work habits, and instruments that are difficult to manipulate.⁵⁻¹³,¹⁴

The nature of dentistry requires very good fine motor co-ordination of the dominant hand and occasional forceful grip strength. The non-dominant hand is generally used as an aid to improve the view of the working field, e.g., to use a dental mirror. This also requires a static and often forceful grip. Moreover, tasks which demand a high level of visibility during simultaneous fine manipulation and reach are highly demanding work postures, with large muscular loads on the neck, arms and hands.\(^1\)

The measurement of external loads and posture of the shoulder and arm during the dentist's working day are necessary to understand the nature of MSDs. Electromyography (EMG) recordings from shoulder and arm muscles, especially from the trapezius muscle, have been used to estimate loads during work both in the field and in laboratory studies. Regarding biomechanics, earlier studies have found that dentists are exposed to a high demand on the trapezius muscles bilaterally, due to forward bending of the head.\(^3\) Prolonged static postures are thought to be related with various MSDs. Requiring a good visual field, dentists must access the teeth with the arms in abduction for an extended period of time. In addition the cervical spine is flexed forward and rotated which can produce pain and muscle spasms. Tenderness in the upper trapezius muscle (trapezius myalgia), is often seen on the side on which the dentist grasps the mirror.\(^5\)

The purpose of this study was to compare trapezius muscle activity while performing simulated dental activities in a dental chair with chest and arm support with the same activities being performed in an ordinary dental chair. Our hypothesis was that using a chest and arm support when working could decrease trapezius muscle activity while still maintaining maneuverability of the dentist.

**Materials and Methods**

**Design of the Arm and Chest Rest**

Initially we made a padded chest rest with a pivot at its connection to the seat pan of an ordinary dental chair (Fig 1) in which trapezius muscle activity was compared to without using padded chest rest by three subjects. Following their feedback, the chair was modified by building an arm rest for each hand into the original design. The newly ergonomically designed chair (EDC) was then subjected to both subjective and objective evaluations. All of the parts in the EDC (Figs 2 and 3) were designed to be fully adjustable by the user.

**Objective Evaluation with Laboratory Experiment**

**Participants:** Twelve right-handed male volunteers from Sharif University of Technology participated in this study.
None of them had any significant history of low-back pain or other MSDs. The mean±SD age, stature, and weight of the subjects were 25.2±2.2 years, 176±6 cm, and 70.6±9.4 kg, respectively.

**Apparatus:** Two pairs of surface EMG electrodes (designed using two cone-shaped silver contacts with an inter-electrode distance of 13 mm) were used (MyoSense, Kardanan Yeganeh Asia [KYA], Iran) to capture electrical activities of sampled muscles after proper preparation of the skin to reduce impedance. For electrode placement over the upper trapezius, two electrodes were placed bilaterally on the skin of the subjects to a point 2 cm lateral to one-half the distance between the C7 spinous process and the lateral tip of the acromion. For the middle trapezius, two electrodes were placed parallel to the muscle fibers between the spine of the scapula and thoracic spine to a point 3 cm lateral to the second thoracic spinous process. The ground electrode was placed on the upper thoracic vertebra, T1. EMG data was collected for 15 seconds during each trial with a sampling frequency of 1024 Hz.

**Experimental design:** In this study, one independent variable, “chair” with two levels of “ordinary chair” and “EDC,” and four dependent variables, the normalized EMG activity of the four muscles, were considered.

**Experimental procedures:** Upon completion of a short warm up, the electrodes were placed over specified locations and the signals were verified, then subjects were asked to pull a table upward while they were standing. The table was fixed on the floor so that the subject could reveal their maximum voluntary contraction (MVC). These data were collected to normalize the EMG activity of each muscle for each subject with respect to their maximum EMG activity. EMG signals
were recorded for 3 seconds during the MVC trial. After subjects learned about a set of routine examination tasks without using mirror performed on teeth of lower jaw, EMG data was collected while performing a set of routine examination tasks in about 15° to 30° trunk and 20° to 40° head sagittally forward flexion angles in an ordinary dental chair and in the EDC. The order in which the chairs were used was randomized and the subject was allowed to adjust the seat to suit their preference. The normalization of each EMG recording was calculated as a percentage of the participants’ muscle activities during MVC.

**Data processing:** Raw EMG data was transformed into frequency domain and band-pass filtered at a high-pass frequency of 10 Hz and a low-pass frequency of 500 Hz. A notch filter was applied to eliminate 60-Hz frequency and its aliases. Then, the data was inverse-transformed to time domain for further analysis. Accordingly, filtered signals were full-wave rectified and averaged across data collection period. This processing was performed for both the data collected during the experimental trials as well as for data collected during the isometric MVC. The EMG signals of the MVC trials were reduced to 1/8th second windows and the peak of the 24 windows (3 seconds exertion) for each individual muscle at each posture was identified and used as the denominator in order to normalize the EMG data from the experimental trials. The EMG from simulated tasks was reduced to 1/8th second windows and the mean of 120 windows (15 seconds data collection) for each individual muscle for each trial was used as the numerator for normalized EMG.

**Analysis:** The raw EMG signals were processed with MATLAB software (Mathworks, Inc.); Paired Student's t test was used to assess the effect of using an EDC on muscle activity in each subject. SAS software (ver 9.1, SAS Institute, Cary, NC) was used for statistical analyses.

**Subjective Experiment**

In this section, our subjects included 30 professional dentists from the dental clinic at Tehran Azad University. The mean±SD age, stature and whole body mass of participants were 38.3±5.9 years,
An Ergonomically Designed Dentistry Chair

TAKE-HOME MESSAGE

- Dentists are at high risk for developing work-related MSDs spatially in neck, shoulder and the back.
- Workstation design, work technique, posture and tools have significant impact on developing MSDs in dentistry.
- It is recommended that introduction of new equipment which reduces postural stress should be introduced as early as possible during practical training of dental students to prevent development of bad postural habits.

For more information on prevalence of musculoskeletal pain among dentists in Shiraz, Iran see www.theijoem.com/ijoem/index.php/ijoem/article/view/26

For more information on ergonomic and anthropometric consideration for library furniture in an Iranian public university see www.theijoem.com/ijoem/index.php/ijoem/article/view/117

175.2±7.5 cm, and 80.8±9.7 kg. For our experiment we provided the subject with the EDC in substitution for the ordinary chair they used regularly during their working hours.

The dentists were asked to use the EDC for a period of one month. Afterwards, they were provided with an 18-item Borg scale questionnaire. Ratings on the questionnaire ranged from ‘0’ (very bad) to ‘10’ (very good). The questions included the amount of adjustability, ease of operation, maintenance, comfort and overall chair experience of the EDC in comparison to the ordinary chair (Table 1). Furthermore, we had a face to face interview with each one dentist to know their comments about EDC.

Results

Compared to ordinary chair, the EDC had a significant (p<0.001) favorable effect on EMG activities of the right upper trapezius, left upper trapezius, right middle trapezius, and left middle trapezius muscles (Fig 4). A proportion of the average measures taken from the upper and middle trapezius indicated that the upper trapezius had a greater decrease of EMG activity than the middle trapezius using the EDC (Fig 4).

Analysis of the dentists’ responses to the questionnaire (Fig 5), revealed that almost all of the subjects preferred the EDC to the ordinary dental chair. However, they pointed out that EDC caused some difficulty while turning around the patient.

Discussion

We conducted this study to evaluate the effects of a chest and arm rest on trapezius muscle activity during normal tasks performed in dentistry. Dentists are regularly subjected to static posture which can require a large amount of muscle activity for stabilization against the moments of upper body weight on shoulder, neck and back muscles. The static forces resulting from these postures have been shown to be much greater than dynamic (moving) forces. In addition, high intensity static contraction generates considerable intramuscular pressure which can reduce blood flow in the muscles. This can cause fatigue, pain and discomfort that if left unattended, can lead to MSDs. The forward-head and rounded-shoulder postures also increase loads on the upper neck muscles (upper trapezius and levator scapulae) and spinal vertebral discs.

As hypothesized, the postural support afforded by the EDC and its arm rests reduced muscle activity significantly. Trapezius muscle activity has been studied previously in dental work research due to the discomfort that is experienced in the neck/shoulder region. The magnitude of NEMG signals of the right side muscles showed higher values than left side muscles because subjects were right handed and they employed their right hand to perform tasks which was asked and they used left hand to conduct the patient’s
Dentists often work in a lean forward sitting posture without any external support. We recognized the need for arm and trunk support that would not restrict the dentist's mobility and functional reach as they go through their complex work duties. Many versions of our conceptual design were assessed based upon the methodology of Pahl. The highest ranking was obtained by the design that was constructed and tested in this study (Fig 2).

Arm support during work has been shown to decrease load of the shoulder muscles. The NEMG signals declined to less than 5% MVC when using EDC. Jonsson defined “static work” as a pure static loading like continuous isometric contraction of certain load levels occurring in dentistry. Static load level in many occupations could be a significant factor to develop fatigue. Accordingly, static load level needs to be less than 5% MVC for continuous and prolonged tasks. Hagberg reported that even elevating an unloaded arm causes a significant fatigue in upper trapezius. Without arm rest, time to fatigue could be reduced to less than 10 minutes when the arms were extended forward just by 20 cm.

When the arm is supported, an external force opposite to the gravity is applied to the arm. A study of dental working postures found that neck flexion exceeded 30° in 82% of the time. Similarly, Akeson, et al, found that neck flexion exceeded 30° in 50% of the time. In this study, subjects showed about 15° of trunk flexion while using the EDC because the chest rest decreased the need for more trunk and neck flexion. Improved posture can theoretically reduce existing musculoskeletal discomfort and prevent development of future MSDs.

Fatigue of muscles of the trunk and shoulders—recruited as postural stabilizer—is a significant factor to develop MSDs in dentistry. Therefore, dentists even need to perform some stretching and strengthening exercise.

The second phase of this study (subjective survey) also confirmed the results of the experimental study. Professional dentists preferred the EDC unanimously. Results showed that the majority of the dentists in this study rated the EDC higher for ease of adjustability and appearance when compared to their ordinary chair. Although a concern which the majority of the dentists identified was difficulty in adapting to the EDC after becoming accustomed to working in their ordinary chair, perhaps for many years. They mentioned that it would be most beneficial for the EDC to be introduced to new dental

### Table 1: The questionnaire with 18 items that included four major categories: the amount of adjustability, ease of operation and maintenance, chair comfort and overall chair experience with a scoring option ranging from 0 (very bad) to 10 (very good) for each question.

<table>
<thead>
<tr>
<th>Adjustment Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Height adjustment range for seat pan</td>
</tr>
<tr>
<td>2. Angle adjustment range for back or chest support</td>
</tr>
<tr>
<td>3. Height and angle adjustment range for armrest.</td>
</tr>
<tr>
<td>4. Independent adjustment of seat pan, armrest, and back or chest support promotes ease of use.</td>
</tr>
<tr>
<td>Chair Comfortability</td>
</tr>
<tr>
<td>5. Comfort level of seat pan while sitting.</td>
</tr>
<tr>
<td>6. Comfort level of back or chest support while sitting.</td>
</tr>
<tr>
<td>7. Comfort level of armrest while sitting.</td>
</tr>
<tr>
<td>Ease of operation and maintenance</td>
</tr>
<tr>
<td>8. Ease of seat pan height adjustment while sitting.</td>
</tr>
<tr>
<td>9. Ease of armrest height adjustment while sitting.</td>
</tr>
<tr>
<td>10. Ease of back or chest support angle adjustment while sitting.</td>
</tr>
<tr>
<td>11. Ease of maintaining the cleanliness of various chair parts.</td>
</tr>
<tr>
<td>12. Ease of descent into the chair.</td>
</tr>
<tr>
<td>Overall chair experience</td>
</tr>
<tr>
<td>13. Adequate number of chair support parts.</td>
</tr>
<tr>
<td>14. Ease of chair use and control while sitting, moving, or during adjustment.</td>
</tr>
<tr>
<td>15. Chair stability.</td>
</tr>
<tr>
<td>16. Chair aesthetics.</td>
</tr>
<tr>
<td>17. Overall chair comfort</td>
</tr>
<tr>
<td>18. Overall chair experience</td>
</tr>
</tbody>
</table>

---

O. Haddad, M. A. Sanjari, et al
students before they developed bad habits using the ordinary chair. The dentists also pointed out an additional concern that must be addressed before final production of the EDC; they mentioned that the EDC caused some difficulty by getting in the way of their work when working between the 8 and 11 o’clock position relative to the patient (Fig 6).

Future studies should incorporate EMG and noninvasive techniques, i.e., using vision technology or wearable inertial guidance sensors, over an entire work day so that dentists can be studied more comprehensively while performing their normal work duties while using the EDC.\(^ {28} \)

Within the results and limitations of this study, it has been demonstrated that incorporating a chest and arm rest into a dental chair may reduce the back and shoulder problems that arise from prolonged flexed trunk posture with abducted shoulders encountered by many dentists. The activity of the shoulder muscles was significantly reduced when using these modified chairs. This reinforces the biomechanical rationale of reducing the external load which can be accomplished utilizing a chest and arm support. The decreased muscle activity and improved subjective rating of the modified chair are attributed to improved posture by reducing the required neck and trunk flexion. It is recommended that introduction of new equipment which reduces postural stress should be introduced as early as possible during practical training of dental students to prevent development of bad postural habits. We continue to be involved in improving the design of the EDC and arm rest to avoid any restrictions in the entire workspace essential for dental procedures with patients.

**Acknowledgements**

This study was partially supported by a grant from the Nilper Company, Iran. Partial support was provided by Hanyang University Research Foundation HY-2009-N9 to M. Parnianpour to complete the project report. Valuable assistance was given by Mrs. Afsoon Motallebi, a dentistry student in the dental clinic at Tehran Azad University. Part of the experiment was conducted at the Rehabilitation Research Center of Iran University of Medical Sciences.

**Conflicts of Interest:** None declared.

**References**


