Assessment of the ergonomic risk from saddle and conventional seats in dentistry: A systematic review and meta-analysis

Giovana Renata Gouveia1*, Walbert de Andrade Vieira2*, Luiz Renato Paranhos3*, Ítalo de Macedo Bernardino4*, Jaqueline Vilela Bulgareli1*, Antonio Carlos Pereira1*

1 Department of Community Dentistry, School of Dentistry of Piracicaba, University of Campinas, Piracicaba, SP, Brazil, 2 Department of Dentistry, University of Sergipe, Aracaju, SE, Brazil, 3 Department of Preventive and Community Dentistry, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil, 4 Postgraduate Program in Dentistry, State University of Paraíba, Campina Grande, PB, Brazil

* These authors contributed equally to this work.
* gigouvea@hotmail.com

Abstract

Objective

This study aimed to verify whether the saddle seat provides lower ergonomic risk than conventional seats in dentistry.

Methods

This review followed the PRISMA statement and a protocol was created and registered in PROSPERO (CRD42017074918). Six electronic databases were searched as primary study sources. The "grey literature" was included to prevent selection and publication biases. The risk of bias among the studies included was assessed with the Joanna Briggs Institute Critical Appraisal Tool for Systematic Reviews. Meta-analysis was performed to estimate the effect of seat type on the ergonomic risk score in dentistry. The heterogeneity among studies was assessed using I² statistics.

Results

The search resulted in 3147 records, from which two were considered eligible for this review. Both studies were conducted with a total of 150 second-year dental students who were starting their laboratory activities using phantom heads. Saddle seats were associated with a significantly lower ergonomic risk than conventional seats [right side (mean difference = -3.18; 95% CI = -4.96, -1.40; p < 0.001) and left side (mean difference = -3.12; 95% CI = -4.56, -1.68; p < 0.001)], indicating posture improvement.

Conclusion

The two eligible studies for this review provide moderate evidence that saddle seats provided lower ergonomic risk than conventional seats in the examined population of dental students.
Introduction

Occupational health has been extensively investigated in dentistry [1–4], considering that dentists are professionals highly vulnerable to musculoskeletal diseases [5,6], especially in the cervical and lumbar spines [7]. Working posture is the main risk factor for developing musculoskeletal disorders [8–9].

The sitting posture is the body position that dentists use most frequently [10]. The dental stool has an influence on such posture [11–13], because it induces the use of certain postural patterns to find a more comfortable and/or functional position [11–13]. In addition, the curvature of the spine, as well as the location and correct position of the head and pelvis are crucial for the biomechanics of the sitting position [14–16].

There is evidence that the 90˚ sitting posture (knee angle and hip angle) increases the passive tension of hamstring muscles, causing a posterior pelvic rotation and resulting in a kyphotic sitting posture of the lumbar spine [17–18]. However, ergonomic recommendations [19], radiographic studies [17–18], and analyses from physical therapists [20] and laypersons [21,22] indicate that a sitting posture with a slight anterior tilt of the lumbar spine and a slight lumbar lordosis of the lumbar spine reduces the incidence of low back pain most efficiently.

Aiming to reduce postural problems in dentistry, scientific studies have been performed to elucidate the impact of different types of seats on the posture of students and trained professionals [16,23], as well as the importance of ergonomic seat interventions [14] in reducing musculoskeletal symptoms [15]. However, the literature does not yet provide a consensus on whether the saddle seat is a superior alternative to the conventional seat for maintaining optimal posture.

Thus, the present study aimed to answer the following guiding question (based on the PICO strategy): “Does the saddle seat (intervention) provide lower ergonomic risk (outcome) to dentists and/or dental students (population) when compared with conventional seats (comparison)?” The authors have tested the hypothesis that using the saddle seat will promote lower ergonomic risk than the conventional seat.

Methods

Protocol and registry

This systematic review was performed following the PRISMA (S1 PRISMA Checklist) statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [24] and the Cochrane guidelines [25]. The systematic review protocol was registered in the PROSPERO database under number CRD42017074918 (https://www.crd.york.ac.uk/PROSPERO/).

Study design and eligibility criteria

The review included only randomized controlled trials that compared the working posture of dental students and/or dentists in conventional seats without ergonomic changes and in ergonomic saddle seats. There were no restrictions of year, language, or publication status (ahead of print).

The following were excluded: 1) Studies not related to the topic; 2) Reviews, letters to the editor, personal opinions, book/book chapters, didactic material, reports, abstracts, and patents; 3) Qualitative or prevalence studies; and 4) Studies that used other types of seats or modified seats.

Sources of information and research

The primary sources of research were the electronic databases Embase, Latin American and Caribbean Health Sciences (LILACS), PubMed (including MedLine), SciELO, Scopus, and
Web of Science. OpenThesis and OpenGrey were used to collect the "grey literature", avoiding selection and publication biases. A manual search was also performed through a systematic analysis of the references of the eligible articles.

Two eligibility reviewers conducted the research independently (GG and WAV). The DeCS (Descriptors in Health Sciences– http://decs.bvs.br) and MeSH (Medical Subject Headings– https://www.ncbi.nlm.nih.gov/mesh) resources were used for keyword selection. The Boolean operators “AND” and “OR” were applied to enhance the search strategy through several combinations (S1 Table). The bibliographical research was developed and performed in August 2017. The search strategy included the following MeSH, DeCS, and Emtree terms: 'Dentists', 'Posture', 'Human Engineering', 'Odontologia' [Portuguese], 'Postura' [Portuguese] associated with the entry terms: 'Dental students', 'Student of dentistry', 'Undergraduate student of dentistry', 'Seated Position', 'Sitting Position', 'Saddle chair', 'Saddle seat'. The records obtained were exported to the software EndNote Basic/Online, desktop version (Thomson Reuters, New York, USA) and duplicates were removed.

Selection of studies
The studies were selected in three stages. In stage 1, two reviewers (GG and WAV) performed a systematic analysis of the titles, independently. The articles whose titles met the objectives of the study were selected for stage 2, when both reviewers (GG and WAV) also performed a systematic analysis of the abstracts. At this time, the studies not related to the topic, reviews, letters to the editor, personal opinions, book/book chapters, didactic material, reports, abstracts, patents, qualitative or observational studies, and studies that used other types of seats or modified ones were excluded. The articles whose titles met the study objectives, but had no abstract, were fully reviewed.

In the third stage, the full texts of the preliminary eligible studies were obtained and evaluated to verify whether they met the eligibility criteria. When both reviewers could not reach an agreement, a third reviewer (LRP) was consulted to make a final decision. Rejected studies were recorded separately along with the explicit reasons for exclusion.

Process of data collection and extraction
After the selection, two authors (MSS and WAV) analyzed the studies, which data were extracted for the following information: article identification (author, year, study location), sample characteristics (number of patients in each study, mean age, sex distribution, school year), type of intervention (seat type, training time, evaluation start time), and methods for obtaining the results (methods used for posture evaluation, image analysis, and calibration time). Any disagreement was discussed and a third reviewer (LRP) was consulted when necessary.

Individual risk of bias of the studies
The risk of bias in the studies selected was assessed using the Joanna Briggs Institute Critical Appraisal tools for use in JBI Systematic Reviews for Randomized Controlled Trials [26]. Two authors (WAV and LRP) independently assessed each domain for the potential risk of bias. The following questions were used for the assessment: 1) Was true randomization used for assigning the participants to treatment groups? 2) Was the allocation to treatment groups concealed? 3) Were treatment groups similar at baseline? 4) Were participants blind to treatment assignment? 5) Were those delivering treatment blind to treatment assignment? 6) Were outcome assessors blind to treatment assignment? 7) Were treatment groups treated identically other than the intervention of interest? 8) Was follow-up complete, and if not, were differences
between groups in terms of their follow-up adequately described and analyzed? 9) Were participants analyzed in the groups to which they were randomized? 10) Were outcomes measured in the same way for treatment groups? 11) Were outcomes measured in a reliable way? 12) Was appropriate statistical analysis used? 13) Was the trial design appropriate, and were any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial? The risk of bias was categorized as High when the studies reached up to 49% of “yes” score, Moderate when they reached 50% to 69% of “yes” score, and Low when the studies reached more than 70% of “yes” score. Studies categorized as either high risk of bias or low methodological quality were eliminated.

**Outcome measures and data analysis**

The meta-analysis for continuous outcome was performed to estimate the effect of seat type on the ergonomic risk score in dentistry [25]. The mean difference was used for pooling effects. Heterogeneity among studies was assessed using $I^2$ statistics and classified as follows: low ($I^2 < 25\%$), moderate ($I^2 = 50\%$), and high ($I^2 > 75\%$) [27]. The random-effects model was selected to minimize the effect of heterogeneity among studies [28]. Publication bias was not assessed because there was not a sufficient number of studies to group in a funnel plot. The software Review Manager, version 5.3 (RevMan, Cochrane Collaboration) was used to perform all statistical analyses.

**Confidence in cumulative evidence**

The Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) tool [28] assessed evidence quality and grading of recommendation strength. This assessment was based on study design, methodological limitations, inconsistency, indirectness, imprecision, and other considerations. Evidence quality was characterized as high, moderate, low, or very low [29].

**Results**

**Selection of studies**

The bibliographical research was developed and performed in August 2017. During the first stage of study selections, 2993 records were found in six electronic databases. After removing the repeated/duplicated records, 1918 articles proceeded to the analysis of titles and abstracts. A total of 154 studies from the “grey literature” was found through the search strategy, although only one was related to the objectives of the present review. After the analysis of titles and abstracts, only three studies were eligible for full-text analysis. The references of the initially eligible studies were carefully assessed to verify potential articles that were absent from the main search strategy. However, from the three studies included in this stage, one of them was excluded for being a thesis from which an eligible article was produced. Therefore, two articles proceeded to the analysis of results. Fig 1 reproduces the process of search, identification, inclusion, and exclusion of articles.

**Characteristics of the studies**

Both eligible studies [11–12] commented on the research ethical criteria and explained the use of consent forms for research subjects. None of the studies presented either sample calculation or study power. The analysis resulted in a total sample of 150 dental students and there were no studies with professional dentists. The studies were performed in the United Kingdom [11] in 2007 and in India [12] in 2014. One study compared the Salli Saddle Chair and a
conventional chair with and without back rest and flat surface [12], and the other compared a Bambach Saddle Seat and a conventional chair with back rest and flat surface [11]. Both studies [11–12] were performed with second-year dental students, who were starting their laboratory activities using phantom heads.

The participants of the eligible studies [11–12] received training as to correct posture and use of each seat type. The evaluation was performed after 10 [11] or 12 [12] weeks so the students would get used to the seats. Table 1 presents a summary of the main characteristics of these studies.
Risk of bias in the studies

Both studies included in this review [11–12] presented low risk of bias in the Joanna Briggs Institute Critical Appraisal tool [26]. Table 2 shows detailed information on the risk of bias of the studies included.

Results of individual studies and meta-analysis

The studies selected used the RULA (Rapid Upper Limb Assessment) method [30], which analyzes the overload concentrated in the neck and upper limbs during work and assesses the static muscle work and the forces exerted by the segments analyzed. The calibration time set by the studies ranged from 10 [11] to 15 [12] minutes so that the students could focus on their work and be evaluated afterwards. In both studies, the students prepared a mandibular tooth in a mannequin.

In the study by Gandavadi et al. [11], photographs were taken of both left and right sides, while in the study by Dable et al. [12], the analysis was performed from static images captured from videos. The results showed lower scores for the ergonomic seats (Salli Saddle Chair and Bambach Saddle Seat) than for conventional seats. In the study by Dable et al. [12], the authors also used image magnification lenses to compare the groups, showing even lower scores with such system.

Table 1. Summary of the main characteristics of the eligible studies.

| Author, year, and country | Seat type | Sample (n) | School period | Location | Procedure performed | Training time | Time of assessment | Evaluation method | Analysis method | Calibration time |
|---------------------------|-----------|------------|---------------|----------|---------------------|---------------|-------------------|------------------|----------------|----------------|
| Gandavadi et al., 2007, United Kingdom | Bambach Saddle Seat (BSS) Conventional Seat (CS) | Bambach Saddle Seat: 30 Conventional Seat: 30 | 2nd year | Preclinical laboratory | Cavity preparation of mandibular teeth in a mannequin | 10 weeks | 2 weeks | RULA* | Photos | 10 minutes |
| Dable et al., 2014, India | Salli Saddle Chair (SSC) Conventional chair with back rest (CC1) Conventional chair without back rest (CC2) | Salli Saddle Chair: 30 Conventional chair with back rest: 30 Conventional chair without back rest: 30 | 2nd year | Preclinical laboratory | Cavity preparation of the first mandibular premolar in a mannequin | 12 weeks | 3 days | RULA* | Videos | 15 minutes |

*RULA: Rapid Upper Limb Assessment.

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Table 2. Risk of bias assessed by the Joanna Briggs Institute Critical Appraisal Tools for use in JBI Systematic Reviews for Randomized Controlled Trials* [26].

| Authors | Q.1 | Q.2 | Q.3 | Q.4 | Q.5 | Q.6 | Q.7 | Q.8 | Q.9 | Q.10 | Q.11 | Q.12 | Q.13 | %yes/risk |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----------|
| Gandavadi et al., 2007 | ✓ | ✓ | ✓ | — | ✓ | — | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 84.6%/Low |
| Dable et al., 2014 | ✓ | ✓ | ✓ | — | ✓ | — | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 84.6%/Low |

1) Was true randomization used for assigning the participants to treatment groups? 2) Was the allocation to treatment groups concealed? 3) Were treatment groups similar at baseline? 4) Were participants blind to treatment assignment? 5) Were those delivering treatment blind to treatment assignment? 6) Were outcome assessors blind to treatment assignment? 7) Were treatment groups treated identically other than the intervention of interest? 8) Was follow-up complete, and if not, were differences between groups in terms of their follow-up adequately described and analyzed? 9) Were participants analyzed in the groups to which they were randomized? 10) Were outcomes measured in the same way for treatment groups? 11) Were outcomes measured in a reliable way? 12) Was appropriate statistical analysis used? 13) Was the trial design appropriate, and were any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial? NA = Not Applicable; ✓ = Yes; “—” = No.

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Fig 2 presents the forest plots. The mean differences in ergonomic risk score and their respective 95% confidence intervals are represented by squares for the individual studies. The S2 Table shows the risk score of individual studies. The diamonds at the bottom represent the pooled mean ergonomic risk score with 95% confidence interval. The meta-analysis results showed that saddle seats are associated with significantly lower ergonomic risk scores when compared with conventional seats [right side (mean difference = -3.18; 95% CI = -4.96, -1.40; \( p < 0.001 \)) and left side (mean difference = -3.12; 95% CI = -4.56, -1.68; \( p < 0.001 \))], indicating posture improvement. The overall mean difference in ergonomic risk score was -3.16 (95% CI = -4.02, -2.30; \( p < 0.001 \)). Between-study heterogeneity was high (\( I^2 = 95\% \); \( p < 0.001 \)).

Confidence in cumulative evidence

Overall, the quality of evidence from the outcomes evaluated by the GRADE system [29] was assessed as moderate (Table 3).

Discussion

This study aimed to compare the ergonomic risk of saddle and conventional seats used in work practices of dentists and/or dental students. Both eligible studies [11–12] were performed with a convenience sample (dental students). Studies with trained professionals may result in...
bias due to the different situations of the clinical routine. Forming a control group for this type of study, paired with the experimental group for age and time of profession, would represent another challenge. These variables may reflect especially in existing musculoskeletal diseases and in the resistance for changing usual postural practices [31–32]. Thus, the results of the present meta-analysis with studies performed with dental students significantly favor saddle seats over conventional seats, which confirms the initial hypothesis.

In both eligible studies [11–12], dental students were instructed to prepare a cavity in the mandibular teeth of a mannequin, at the preclinical laboratory. It is known that a procedure performed in a dental mannequin does not reproduce the actual reality of a dentist’s routine. This is because a real patient presents variables such as age (elderly people or children), anatomical structures (tongue, cheek, and mouth opening limitation), special care (physical and/or mental disabilities), altered psychological states (fear and/or anxiety), obesity, and pregnancy, which may change and complicate the operational procedure. However, in the preclinical laboratory during procedures in mannequins, students experience the first body postures, adapting their body to seat, static posture, reduced field of vision, dental procedure, precision of fine movements, and especially to the fear and insecurity of dealing with something new [33].

One of the methods for verifying ergonomic risks is the Rapid Upper Limb Assessment (RULA) [30], which is the most cited in the literature and used in both eligible studies [11–12] of this review. In this method, the positions of individual body segments are observed and assessed with increasing scores according to the growing deviation of the neutral posture [30]. Different studies [30–34] have assessed the validity and reliability of the RULA, which is considered an adequate method to assess the body posture of dentists [35] and dental students [36]. The observations of evaluators regarding the static image may be associated with the uncertainty regarding camera angle [37].

Gandavadi et al. [11] observed the working postures of both right and left sides using digital photographs. Dable et al. [12], in turn, used videos that were paused at every postural position and at every body movement of both right and left sides. However, the assessment and final score of both studies [11–12] were based on a static image. The assessment of the body posture images of the research participants started after 10 to 15 minutes in a familiar environment. Given the long time for capturing the images, the participants were likely focused on the activity proposed and kept the postural habits of their usual routine, which canceled the Hawthorne effect—a phenomenon in which participants change their behavior when they are aware of being watched.

In this study, the ergonomic risk was assessed in groups that used conventional and saddle seats. The results indicated an intermediate to high score for ergonomic risk in the group using the conventional seat, which is consistent with other studies [36,39]. Over the last decade, research has been intensified, designing the effects of different seats on the clinical practice of dentists and dental students [11–13,40–42]. Among such studies, three have investigated the ergonomically modified stool [40–42] and three have investigated the saddle seat [11–13]. All studies showed an improvement in the experimental group when compared to the control group, especially for presenting a lumbar lordosis seated posture [11–13].

There is a consensus among several studies [17–21,43–49] that the lumbar lordosed seated posture is optimal for favoring a neutral lumbar posture, minimizing the painful symptomatology of low back pain. It is also associated with high muscular activity and the increase in spinal load due to the posterior pelvic tilt, which is then balanced by muscle contractions in the dorsal spine, representing a dynamic posture [50]. This posture is obtained by positioning the lower lumbar spine in a slight forward tilt and slight lumbar lordosis, while maintaining the relaxation of the muscles surrounding the thoracic spine [20].

In occupational science, a static body posture is defined as a posture held for more than four seconds [51–52]. Static work procedures prevent the blood flow required for tissue...
recovery. Other significant factors are the frequency of occurrence, the pauses during movement, and the duration (time component) for maintaining a static body posture [53]. Consequently, several dental tasks are performed in static postures with the prolonged flexion and/or rotation of the trunk, presenting a potential risk for the musculoskeletal system [53].

The interdisciplinarity between bioengineering and health sciences improves clinical relevance and research [19,54–56]. Dynamic seats [57–58] with a slight forward inclination [54,56–59], with or without a low backrest [57] to support the ischia [19,60], are the challenges of novel seat designs. However, it is worth noting that adopting a good posture and using the correct furniture are not enough to reduce the overload on the osteomyoarticular tissues of dentists [61–62]. Besides seat design, the human, occupational, and organizational factors also play an important role in terms of load conditions in the human body [63–65]. Psychosocial factors are also major risk factors for persistent low back pain in workers, and they should be considered along with the physical labor requirements, reducing the disability related to lumbar pain [66]. Such pain is also directly associated with depression and somatization [67]. Psychosocial interventions may reduce the impact of low back pain in the workplace [68,69].

Four-handed dentistry, equipment organization in the workspace, correct positioning of patients, illumination, and auxiliary components should be observed and controlled in the dental clinical practice [61–62]. The musculoskeletal stress of a dental professional is quantifiable, comparable, and especially rather variable, considering that musculoskeletal disorders may be reduced by improving the ergonomic positioning of the patient and the practitioner [70]. Positioning should maintain the natural curves of the lumbar spine (cervical lordosis, thoracic kyphosis, lumbar lordosis, and sacral kyphosis), allowing a neutral sitting posture [7,59] so that muscles and intervertebral discs may alternate between relaxation and loading. Correct positioning is beneficial for nourishing muscles [71] and intervertebral discs [72] and for potentially reducing ergonomic risks.

The present review is original, and it has contributed to develop the scientific knowledge from two main points. Primarily, it is the first systematic literature review to investigate the influence of seat type on ergonomic risk among dental students. Second, the low risk of bias observed in the eligible studies allows drawing more consistent and reliable conclusions from the data obtained, producing major implications for the academic dental clinical practice.

Limitations

The present study is limited by the presence of only two clinical studies on the subject, with no sample calculation or study power. In addition, the student population included only dental students working on phantom heads and it was not sex-specific. In both studies included, the data were collected only at the end of follow-up. It is worth noting that short-term investigations of the sitting posture may not completely represent the biological time-dependent responses. Further studies should be performed to determine whether the effectiveness of a saddle seat intervention is maintained in the long-term, especially concerning the neutral lumbar posture. In addition, both eligible articles used static images to represent the average posture of a person, which does not fit the reality. Therefore, further studies need to employ state of the art posture measurement equipment that automatically record the posture continuously. A combination of posture and Electro-myography (EMG) measurement would provide additional insight.

Conclusion

The two eligible studies for this review provide moderate evidence that saddle seats provided lower ergonomic risk than conventional seats in the examined population of dental students. Follow-up studies are required to confirm this result by addressing the limitations of the
studies. For example, follow-up studies should employ state of the art posture measurement equipment and examine whether saddle seats also provide lower ergonomic risk in a population of professional dentists treating real patients.

**Supporting information**

S1 PRISMA Checklist. PRISMA checklist. (DOC)

S1 Table. Strategies for database search. (DOCX)

S2 Table. Main results of eligible articles. (DOCX)

**Author Contributions**

Conceptualization: Giovana Renata Gouvêa, Luiz Renato Paranhos, Jaqueline Vilela Bulgareli, Antonio Carlos Pereira.

Formal analysis: Giovana Renata Gouvêa, Ítalo de Macedo Bernardino.

Investigation: Giovana Renata Gouvêa, Luiz Renato Paranhos.

Methodology: Giovana Renata Gouvêa, Walbert de Andrade Vieira, Luiz Renato Paranhos, Jaqueline Vilela Bulgareli, Antonio Carlos Pereira.

Resources: Giovana Renata Gouvêa.

Supervision: Giovana Renata Gouvêa, Jaqueline Vilela Bulgareli, Antonio Carlos Pereira.

Writing – original draft: Giovana Renata Gouvêa, Walbert de Andrade Vieira, Luiz Renato Paranhos, Ítalo de Macedo Bernardino, Jaqueline Vilela Bulgareli, Antonio Carlos Pereira.

Writing – review & editing: Giovana Renata Gouvêa, Walbert de Andrade Vieira, Luiz Renato Paranhos, Ítalo de Macedo Bernardino, Jaqueline Vilela Bulgareli, Antonio Carlos Pereira.

**References**

1. Presotto CD, Wajngarten D, Domingos PAS, Campos JADB, Garcia PPNS. Dental Students’ Perceptions of Risk Factors for Musculoskeletal Disorders: Adapting the Job Factors Questionnaire for Dentistry. J Dent Educ 2018; 82:47–53. https://doi.org/10.21815/JDE.018.007 PMID: 29293255

2. Moodley R, Naibo S, Wyk JV. The prevalence of occupational health-related problems in dentistry: A review of the literature. J Occup Health 2018; 60:111–125. https://doi.org/10.1539/joh.17-0188-RA PMID: 29213011

3. Alyahya F, Algarzaie K, Alsubeh Y, Khounganian R. Awareness of ergonomics & work-related musculoskeletal disorders among dental professionals and students in Riyadh, Saudi Arabia. J Phys Ther Sci 2018; 30:770–776. https://doi.org/10.1589/jpts.30.770 PMID: 29950762

4. Shams-Hosseini NS, Vahdati T, Mohammadzadeh Z, Yeganeh A, Davoodi S. Prevalence of Musculoskeletal Disorders among Dentists in Iran: A Systematic Review. Mater Sociomed 2017; 29:257–262. https://doi.org/10.5455/msm.2017.29.257-262 PMID: 29284995

5. Feng B, Liang Q, Wang Y, Andersen LL, Szeto G. Prevalence of work-related musculoskeletal symptoms of the neck and upper extremity among dentists in China. BMJ Open 2014; 4:e006451. https://doi.org/10.1136/bmjopen-2014-006451 PMID: 25526795

6. Tirgar A, Javanshir K, Talebian A, Amini F, Parhiz A. Musculoskeletal disorders among a group of Iranian general dental practitioners. J Back Musculoskelet Rehabil 2015; 28:755–59. https://doi.org/10.3233/BMR-140579 PMID: 25547232
7. Szczygieł E, Zielonka K, Mętel S, Golec J. Musculo-skeletal and pulmonary effects of sitting position—a systematic review. Ann Agric Environ Med 2017; 24:8–12. https://doi.org/10.5604/12321966.1227647 PMID: 28378964

8. Rafie F, Zamani Jam A, Shahravan A, Raof M, Eskandarizadeh A. Prevalence of Upper Extremity Musculoskeletal Disorders in Dentists: Symptoms and Risk Factors. J Environ Public Health 2015; 2015:517346. https://doi.org/10.1155/2015/517346 PMID: 26064141

9. De Sio S, Traversini V, Rinaldo F, Colasanti V, Buomprisco G, Perri R, Mormone F, La Torre G, Guerra F. Ergonomic risk and preventive measures of musculoskeletal disorders in the dentistry environment: an umbrella review. PeerJ 2018; 6:e4154. https://doi.org/10.7717/peerj.4154 PMID: 29362689

10. Endo K, Suzuki H, Nishimura H, Tanaka H, Shishido T, Yamamoto K. Sagittal lumbar and pelvic alignment in the standing and sitting positions. J Orthop Sci 2012; 17:682–86. https://doi.org/10.1007/s00776-012-0281-1 PMID: 22915074

11. Gandavadi A, Ramsay JRE, Burke FJT. Assessment of dental student posture in two seating conditions using RULA methodology—a pilot study. Br Dent J 2007; 203:601–05. https://doi.org/10.1038/ bdj.2007.1047 PMID: 18037853

12. Dable RA, Wasnik PB, Yeshwante BJ, Musani SI, Patil AK, Nagmode SN. Postural Assessment of Students Evaluating the Need of Ergonomic Seat and Magnification in Dentistry. Indian Prosthodont Soc 2014; 14:51–58. https://doi.org/10.1016/s1319-014-0364-0 PMID: 26199492

13. De Bruyne MA, Van Renterghem B, Baird A, Palmans T, Danneels L, Dolfens M. Influence of different stool types on muscle activity and lumbar posture among dentists during a simulated dental screening task. Appl Ergon 2016; 56:220–226. https://doi.org/10.1016/j.apergo.2016.02.014 PMID: 26975788

14. Driessen MT, Proper KI, van Tulder MW, Amersfoort T, Danneels L, Dolphens M. Influence of different stool types on muscle activity and lumbar posture among dentists during a simulated dental screening task. Appl Ergon 2016; 56:220–226. https://doi.org/10.1016/j.apergo.2016.02.014 PMID: 26975788

15. van Niekerk SMS, Louw QQA, Hillier SS. The effectiveness of a chair intervention in the workplace to reduce musculoskeletal symptoms. A systematic review. BMC Musculoskeletal Disord 2012; 13:145. https://doi.org/10.1186/1471-2474-13-145 PMID: 22889123

16. Curran M, O’Sullivan L, O’Sullivan P, Dankaerts W, O’Sullivan K. Does Using a Chair Backrest or Reducing Seated Hip Flexion Influence Trunk Muscle Activity and Discomfort? A Systematic Review. Hum Factors 2015; 57:1115–48. https://doi.org/10.1177/0018720815591905 PMID: 26175544

17. Hey HW, Wong CG, Lau ET, Tan KA, Lau LL, Liu KG, et al. Differences in erect sitting and natural sitting spinal alignment-insights into a new paradigm and implications in deformity correction. Spine J 2017; 17:183–89. https://doi.org/10.1016/j.spinee.2016.08.026 PMID: 27562103

18. De Carvalho D, Grondinb D, Callaghanc J. The impact of office chair features on lumbar lordosis, intervertebral joint and sacral tilt angles: a radiographic assessment. Ergonomics 2016; 60:1393–04. https://doi.org/10.1080/00140139.2016.1265670 PMID: 27915585

19. Corlett EN. Background to sitting at work: research-based requirements for the design of work seats. Ergonomics 2006; 49:1538–46. https://doi.org/10.1080/00140130600766261 PMID: 17050393

20. O’Sullivan K, O’Dea P, Dankaerts W, O’Sullivan P, Clifford A, O’Sullivan L. Neutral lumbar spine sitting posture in pain-free subjects. Man Ther 2010; 15:557–61. https://doi.org/10.1016/j.math.2010.06.005 PMID: 20638321

21. O’Sullivan K, O’Keeffe M, O’Sullivan L, O’Sullivan P, Dankaerts W. Perceptions of sitting posture among members of the community, both with and without non-specific chronic low back pain. Man Ther 2013; 18:551–56. https://doi.org/10.1016/j.math.2013.05.013 PMID: 23806489

22. O’Sullivan K, McCarthy R, White A, O’Sullivan L, Dankaerts W. Can We Reduce the Effort of Maintaining a Neutral Sitting Posture? A Pilot Study. Man Ther 2012; 17:566–71. https://doi.org/10.1016/j.math.2012.05.016 PMID: 22738884

23. Plessas A, Bernardes Delgado M. The role of ergonomic saddle seats and magnification loupes in the prevention of musculoskeletal disorders. A systematic review. Int J Dent Hyg 2018. https://doi.org/10.1111/idh.12327 PMID: 29318741

24. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009; 339:b2700. https://doi.org/10.1136/bmj.b2700 PMID: 19622552

25. Higgins JPT, Green S (editors): Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from http://handbook.cochrane.org. Accessed 25 Ago 2017.
26. Tufanaru C, Munn Z, Aromataris E, Campbell J, Hopp L. Chapter 3: Systematic reviews of effectiveness. In: Aromataris E, Munn Z (Editors). Joanna Briggs Institute Reviewer's Manual. The Joanna Briggs Institute, 2017. Available from https://reviewersmanual.joannabrigs.org/

27. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med 2002; 21: 1539–58. https://doi.org/10.1002/sim.1186 PMID: 12111919

28. DerSimonian R, Laird N. Meta-analysis in clinical trials revisited. Contemp Clin Trials 2015; 45:139–45. https://doi.org/10.1016/j.cct.2015.09.002 PMID: 26343745

29. DerSimonian R, Laird N. Meta-analysis in clinical trials revisited. Contemp Clin Trials 2015; 45:139–45. https://doi.org/10.1016/j.cct.2015.09.002 PMID: 26343745

30. DerSimonian R, Laird N. Meta-analysis in clinical trials revisited. Contemp Clin Trials 2015; 45:139–45. https://doi.org/10.1016/j.cct.2015.09.002 PMID: 26343745

31. Balshem H, Helfand M, Schunemann HJ, Oxman AD, Kunz R, Brozek J, Vist GE, Falck-Ytter Y, Meerpohl J, Norris S, Guyatt GH. GRADE guidelines: 3. Rating the quality of evidence. J Clin Epidemiol 2011; 64:401–6. https://doi.org/10.1016/j.jclinepi.2010.07.015 PMID: 21208779

32. McAtamney L, Nigel Corlett E. RULA: A survey method for the investigation of work-related upper limb disorders. Appl Ergon 1993; 24:91–9. PMID: 15676903

33. Esquirol Y, Niezborala M, Visentin M, Leguevel A, Gonzalez I, Marquie JC. Contribution of occupational factors to the incidence and persistence of chronic low back pain among workers: results from the longitudinal VISAT study. Occup Environ Med 2017; 74:243–51. https://doi.org/10.1136/oemed-2015-103443 PMID: 27672181

34. Aicardi G, Alvarez J, Cotobal F, Hernandez M, Cumplido M, Lourdes Barrueco. Effect of age and body mass index as risk factor for occupational contingencies in healthcare workers. Occup Environ Med 2017; 74:A138–A139.

35. Hayes MJ, Smith DR, Taylor JA. Musculoskeletal disorders in a 3 year longitudinal cohort of dental hygiene students. J Dent Hyg 2014; 88:36–1 PMID: 24563051

36. Levanon Y, Lerman Y, Gefen A, Ratzon NZ. Validity of the modified RULA for computer workers and reliability of one observation compared to six. Ergonomics 2014; 57:1856–63. https://doi.org/10.1080/00140139.2014.952350 PMID: 25205040

37. Park HS, Kim J, Roh HL, Namkooing S. Analysis of the risk factors of musculoskeletal disease among dentists induced by work posture. J Phys Ther Sci 2015; 27:3651–54. https://doi.org/10.1589/jpts.27.3651 PMID: 26834324

38. Movahhed T, Dehghani M, Arghami S, Arghami A. Do dental students have a neutral working posture? J Back Musculoskeletal Rehabil 2016; 29:859–64. https://doi.org/10.3233/BMR-160702 PMID: 27197705

39. Qu Y, Hwang J, Lee KS, Jung MC. The effect of camera location on observation-based posture estimation. Ergonomics 2012; 55:885–97. https://doi.org/10.1080/00140139.2012.682165 PMID: 22676050

40. Gillespie R. Manufacturing knowledge: A history of the Hawthorne experiments. Cambridge: Cambridge University Press; 1993.

41. Petromilli NSGP, Polli GS, Campos JA. Working postures of dental students: ergonomic analysis using the Ovako Working Analysis System and rapid upper limb assessment. Med Lav 2013; 104:440–47. PMID: 24640381

42. Custódio RA, Brandão JG, Amorim JB. The influence of an abdominal support for a dental stool in the distributions and electrical activity of the longissimus and the superior trapezius muscle in dentists. Work 2012; 41:5652–4. https://doi.org/10.3233/WOR-2012-0908-5652 PMID: 22317641

43. Tran V, Turner R, MacFadden A, Cornish SM, Esliger D, Komiyama K, Chilibeck PD. A dental stool with chest support reduces lower back muscle activation. Int J Occup Saf Ergon 2016; 22:301–4. https://doi.org/10.1080/10803548.2016.1153223 PMID: 27058816

44. Scannell JP, McGill SM. Lumbar posture–should it, and can it, be modified? A study of passive tissue stiffness and lumbar position during activities of daily living. PhysTher 2003; 83:907–917.

45. Dankaerts W, O’Sullivan PB, Burnett A, Straker LM. Differences in sitting postures are associated with non-specific chronic low back pain disorders when subclassified. Spine (Phila Pa 1976) 2006; 31:698–704.

46. Womersley L, May S. Sitting posture of subjects with postural backache. J Manipulative Physiol Ther 2006; 29:213–218. https://doi.org/10.1016/j.jmpt.2006.01.002 PMID: 16584946

47. Pynt J, Mackey MG, Higgs J. Kyphosed seated postures: extending concepts of postural health beyond the office. J Occup Rehabil 2008; 18:35–5. https://doi.org/10.1007/s10926-008-9123-6 PMID: 18256935

48. Claus AP, Hides JA, Moseley GL, Hodges PW. Is ‘ideal’ sitting posture real? Measurement of spinal curves in four sitting postures. Man Ther 2009; 14:404–8. https://doi.org/10.1016/j.math.2008.06.001 PMID: 18793867
48. De Carvalho DE, Soave D, Ross K, Callaghan JP. Lumbar spine and pelvic posture between standing and sitting: a radiologic investigation including reliability and repeatability of the lumbar lordosis measure. J Manipulative Physiol Ther 2010; 33:48–55. https://doi.org/10.1016/j.jmpt.2009.11.008 PMID: 20114100

49. De Carvalho DE, Callaghan JP. Influence of automobile seat lumbar support prominence on spine and pelvic postures: a radiological investigation. Appl Ergon 2012; 43:876–82. https://doi.org/10.1016/j.apergo.2011.12.007 PMID: 22280849

50. Grooten WJ, Ång BO, Hagströmer M, et al. Does a dynamic chair increase office workers’ movements? —Results from a combined laboratory and field study. Appl Ergon 2017; 60:1–11. https://doi.org/10.1016/j.apergo.2016.10.006 PMID: 28166867

51. Standardization ISOI. ISO 11226:2000(en): Ergonomics—Evaluation of static working postures. 2000. https://www.iso.org/buy/13298.html. Accessed 05.10.2017.

52. Delleman NJ, Haslegrave CM, Chaffin DB. Working postures and movements: tools for evaluation and engineering. Boca Raton, London, New York, Washington D.C.: CRC Press; 2004.

53. Ohlendorf D, Erbe C, Nowak J, Hauck I, Hermanns I, Ditchen D, Ellegast R, Gronenberg DA. Constrained posture in dentistry—a kinematic analysis of dentists. BMC Musculoskeletal Disorders 2017; 18:291. https://doi.org/10.1186/s12891-017-1650-x PMID: 28679450

54. Gadge K. An investigation into the immediate effects on comfort, productivity and posture of the Bambach saddle seat and a standard office chair. Work 2007; 29:189–210. PMID: 17942990

55. George SC, Meyerand ME, On behalf of the council of chairs of biomedical Engineering. Challenges and Opportunities: Building a Relationship Between a Department of Biomedical Engineering and a Medical School. Ann Biomed Eng 2017; 45:521–24. https://doi.org/10.1007/s10439-016-1785-1 PMID: 28070773

56. Zemp R, Taylor WR, Lorenzetti S. Seat pan and backrest pressure distribution while sitting in office chairs. Appl Ergon 2016; 53 Pt A:1–9. https://doi.org/10.1016/j.apergo.2015.08.004 PMID: 26674398

57. Kingma I, van Dieën JH. Static and Dynamic Postural Loadings During Computer Work in Females: Sitting on an Office Chair Versus Sitting on an Exercise Ball. Appl Ergon 2009; 40:199–205. https://doi.org/10.1016/j.apergo.2008.04.004 PMID: 18508028

58. van Uffelen JG, Wong J, Chau JY, van der Ploeg HP, Riphagen I, Gilson ND, et al. Occupational Sitting and Health Risks: A Systematic Review. Am J Prev Med 2010; 39:379–88. https://doi.org/10.1016/j.amepre.2010.05.024 PMID: 20837291

59. O’Sullivan K, McCarthy R, White A, O’Sullivan L, Dankaerts W. Lumbar Posture and Trunk Muscle Activation During a Typing Task When Sitting on a Novel Dynamic Ergonomic Chair. Ergonomics 2012; 55:1586–95. https://doi.org/10.1080/00140139.2012.721521 PMID: 23009637

60. Pynt J, Higgs J, Mackey M. Seeking the optimal posture of the seated lumbar spine. Physiotherapy 2001; 17:5–21. https://doi.org/10.1080/09593980151143228

61. Molenbroek JFM, Albin TJ, Vink P. Thirty years of anthropometric changes relevant to the width and depth of transportation seating spaces, present and future. Appl Ergon 2017; 65:130–38. https://doi.org/10.1016/j.apergo.2017.06.003 PMID: 28802432

62. Steinbeek R, Dam LV, Vroome ED. Determinants of occupational diseases in the Netherlands: risks at the individual and the population level. Occup Environ Med 2017; 74:481–8. https://doi.org/10.1136/oem-2017-016117 PMID: 28928493

63. Matsuda K, Kawaguchi M, Isomura T, Inuzuka K. Assessment of psychosocial risk factors for the development of non-specific chronic disabling low back pain in Japanese
workers-findings from the Japan Epidemiological Research of Occupation-related Back Pain (JOB) study. Ind Health 2015; 53:368–77. https://doi.org/10.2486/indhealth.2014-0260 PMID: 26051289

69. Kamper SJ, Apeldoorn AT, Chiarotto A, Smeets RJ, Ostelo RW, Guzman J, van Tulder MW. Multidisciplinary biopsychosocial rehabilitation for chronic low back pain. Cochrane Database Syst Rev 2014;(9): CD000963. https://doi.org/10.1002/14651858.CD000963.pub3 PMID: 25180773

70. Blanc D, Farre P, Hamel O. Variability of musculoskeletal strain on dentists: an electromyographic and goniometric study. Int J Occup Saf Ergon 2014; 20:295–307. https://doi.org/10.1080/10803548.2014.11077044 PMID: 24934426

71. Visser B, Van Dieën JH. Pathophysiology of upper extremity muscle disorders. J Electromyogr Kinesiol 2006; 16:1–16. https://doi.org/10.1016/j.jelekin.2005.06.005 PMID: 16099676

72. Belavý DL, Albracht K, Bruggemann GP, Vergroesen PP, van Dieën JH. Can Exercise Positively Influence the Intervertebral Disc? Sports Med 2016; 46:473–85. https://doi.org/10.1007/s40279-015-0444-2 PMID: 26666742