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The role of ergonomic saddle seats and magnification loupes in the prevention of musculoskeletal disorders. A systematic review.

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8 **The role of ergonomic saddle seats and magnification loupes in the prevention**
9 **of musculoskeletal disorders. A systematic review.**
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40 Running Title: Saddle seats, loupes and musculoskeletal disorders.

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50 Posture, Loupes, Magnification
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ABSTRACT

Objectives: Musculoskeletal disorders affect a high percentage of dentists, dental hygienists and therapists. Static and awkward working postures are considered as major risk factors. Proper seat selection and use of magnification loupes are promoted for their ergonomic benefits. The aim of this review was to evaluate the existing empirical evidence on the effect of the above interventions on a) correction of poor posture and b) reduction in musculoskeletal pain. **Methods:** The review was conducted according to the PRISMA guidelines. The review protocol was registered with PROSPERO (CRD42017058580). The Medline via Ovid, CINHAL via EBSCO, Web of Science, OpenGrey and EThOS electronic databases were searched. Prospective experimental studies were considered for inclusion. The Effective Public Health Practice Project Quality Assessment Tool (EPHPP) was used to assess the methodological quality of the included studies. **Results:** Eight studies were included in the review. Four investigated the effect of loupes on posture and musculoskeletal pain, four the effect of the saddle seats on posture and one of the latter explored the combined effect of magnification and use of saddle seats on posture. **Conclusions:** Based on a limited number of studies, the use of ergonomic saddle seats and dental loupes leads to improved working postures. The use of loupes appears to relieve shoulder, arm and hand pain. However, their effect on neck pain is scarce. None of the studies reported on the effect of the saddle seats on musculoskeletal pain. Future well-powered prospective longitudinal studies are deemed necessary to confirm the conclusions of this review.

250 words

Clinical Relevance

Scientific rationale for study: Musculoskeletal pain can have debilitating consequences on the well-being, working satisfaction, and finances of the modern dental hygienist and therapist. The use of ergonomic saddle seats and magnification loupes is being advocated as an ergonomic solution for poor posture and musculoskeletal pain.

Principal findings: Saddle seats significantly improve the operator's posture. However, evidence on their effect on reducing musculoskeletal pain is scarce. Similarly, magnification loupes appear to improve the operator's posture and provide relief of shoulder pain. An additive effect may exist when the two ergonomic measures are used conjunctively.

Practical implications: Modern dental hygienists and therapists can improve their working posture and prevent back and shoulder pain by adopting the use of a saddle seat and loupes in their daily clinical practice.

INTRODUCTION

Work-related musculoskeletal disorders (MSDs) are one of the main occupational health hazards affecting dental care professionals¹⁻³. Dental hygiene and therapy, alike dentistry, is a visually dependent occupation where the visual demands may require adoption of fixed and sometimes awkward postures of the neck and upper limbs for extended periods of time⁴. The forward-right inclined position has been identified as the most common position amongst dental care professionals⁵. Marklin and Cherney, during a 4 hour period observed that dentists and dental hygienists flexed their trunk at least 30 degrees more than 50 percent of the time, their neck at least 30 degrees 85 percent of the time, and their shoulders were elevated to the side of their trunk at least 30 degrees more than 50 percent of the time respectively⁶. Similarly, dental hygiene and therapy students were found to be exposed to neck flexion of greater than 35 degrees, together with trunk flexion greater than 20 degrees and bilateral elbow flexion greater than 90 degrees while working seated⁷.

Dental postural studies extensively support the notion that awkward static positions and poor posture directly relate to higher prevalence of MSDs and pain⁸⁻¹⁰. Furthermore, forward leaning postures and steep, prolonged forward bending of the head seem to relate to increased neck and shoulder pain¹¹⁻¹⁴.

A recent systematic review suggested that the prevalence of general musculoskeletal pain in dental workers ranges between 64% and 93%. The most prevalent regions for pain in dentists are the back (36.3–60.1%) and neck (19.8–85%), while the hand and wrist regions are the most prevalent regions for dental hygienists (60–69.5%)¹⁵. MSDs are multifactorial. Static and awkward postures, repetition and force, poor lighting, improper positioning of both patient and dental

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3 professional, lack of dental assistant, individual characteristics (physical conditioning,
4 height, weight, general health, gender, age) and stress lead to the development of
5 MSDs ^{7, 16, 17}. The demanding pace of the work seems to contribute to the severity of
6
7
8 the problem. Alexopoulos et al. found a strong association between neck and
9
10 shoulder pain and physical workload of professional dentists ¹⁸. Similarly, other
11
12 studies have shown that the longer the working hours and the higher the number of
13
14 patients seen in a day, the higher the prevalence of musculoskeletal complaints is ¹⁹⁻
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Therefore, it becomes clear that dentists and dental hygiene and therapists are at particularly high risk of developing MSDs during their careers. These may occur as early as undergraduate training ²⁴⁻²⁶ with debilitating consequences on the clinician's practising life and well-being. MSDs are a common reason for dentists and dental hygienists to seek medical care ^{18, 27, 28} and being absent from work ^{18, 29}. Namely, 27.2% of the participants in Rafeemanesh et al. study had been absent from work in the past year because of some kind of musculoskeletal disorder (25.3% for 1–7 days and 1.9% for 8–30 days), whilst the major reason for being absent from work in the past year was back pain (7.1%) ²⁹. In 1984, in the USA, the financial impact of MSD related absenteeism was estimated as a reduction of \$315 per day in billings, when in 2007 statistics from the American Dental Association suggested that average dentists' billings were ten times the above amount ³⁰. The estimated costs involved were \$ 45 billion as measured by compensation costs, lost wages, and lost productivity ^{30, 31}. In the Netherlands, records of Movir, a non-profit insurance company, showed that 35.8% of all claims in 2002 were due to MSDs ³¹. Nonetheless, dental professionals suffering from MSDs may consider to reduce their

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3 working hours ³², and even quit the profession ³² or take early premature retirement
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5 33-35 .
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8 In recent years, the use of ergonomic saddle seats and magnification loupes has
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10 been promoted for its ergonomic benefits. Conventional dentist's chairs or seats
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12 commonly come with a backrest. Dable et al. compared the posture of dental
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14 students using conventional seats with and without backrests and concluded that the
15
16 backrest did not improve their posture ³⁶. When sitting unsupported in a conventional
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18 chair over a long period, often the upper body has a tendency to slump, changing the
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20 spine's natural 's' shape curve into a 'c' shape ³⁷. This flexed, kyphosed posture is
21
22 not conducive to postural health ³⁸. In contrast, preserving the natural curve in the
23
24 lumbar spine (known as lordosis) whilst sitting can decrease intradiscal pressure,
25
26 ligament tension and disc degeneration ³⁸. Evidence from early studies has shown
27
28 that lumbar lordosis is a less iatrogenic posture³⁹ and can reduce or prevent back
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30 pain ⁴⁰⁻⁴². Data from a large-scale Canadian survey indicated that increased use of
31
32 lumbar support on operating seats is associated with decreased reports of MSD pain
33
34 (p=0.007) ⁴³. The Bambach Saddle Seat TM and the Salli Saddle Chair TM are two of
35
36 the most commonly available dental saddle seats designed to achieve such a
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38 posture.
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44 Besides, an increasing number of general dentists, specialists, hygienists and dental
45
46 students are using dental loupes in their daily clinical practice. The magnification
47
48 offered by dental loupes varies between 2.5x and 6.0x ⁴⁴. The majority of loupes
49
50 users opt for 2.5X magnification while both users and non-users have an affinity
51
52 towards the "through the lens" design ⁴⁵. An Australian survey suggested that
53
54 hygienists who wear loupes are less likely to have any neck and shoulder (*OR: 0.46,*
55
56 *95% CI 0.27–0.78, p<0.01*), wrist/hand (*OR: 0.47, 95% CI 0.28–0.80, p<0.01*) (*OR: 0.55,*
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3 95% CI 0.33–0.92, $p < 0.02$) or upper back pain (OR: 0.58, 95% CI 0.34–0.99, $p < 0.05$) than
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5 those not wearing loupes ⁴⁶.
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8 The aim of this review was to collect and use the best available empirical evidence to
9
10 answer the following questions:
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12
13 a) Do ergonomic dental saddle seats alleviate musculoskeletal pain or correct the
14
15 posture of the dental care professionals?
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18 b) Do magnification loupes alleviate musculoskeletal pain or correct the posture of
19
20 the dental care professionals?
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23 24 **STUDY POPULATION AND METHODS**

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27 This systematic review was conducted according to a predefined protocol and
28
29 followed the PRISMA guidelines. The protocol was registered with the International
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31 Prospective Register of Systematic Reviews (PROSPERO) under the registration
32
33 number CRD42016045756.
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36 37 **Search methods and strategy**

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40 A search of the peer-review and grey literature was performed using electronic
41
42 bibliographic databases (MEDLINE via Ovid, CINAHL via EBSCO, Web of Science,
43
44 EThOS and OpenGrey) and manual searching of citations of the eligible studies.
45
46 The last search completed on the 4th of March 2017. MeSH terms, subheadings and
47
48 free text search terms were used in the literature search.
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52 The following search strategy (for MEDLINE) was adapted appropriately for each
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54 database:
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3 (dentist.mp. OR Dentists/ OR Dental Hygienists/ OR Dentistry/) AND (Equipment
4 Design/ OR Human Engineering/ OR ergonomic*.mp. OR magnification.mp. OR
5 Lenses/ OR loupes.mp. OR seat*.mp.) AND Musculoskeletal Diseases/ OR MSD.mp.
6
7 OR Occupational Diseases/ OR Musculoskeletal Pain/ OR Back Pain/ OR Low Back
8 Pain/ OR Shoulder Pain/ OR Neck Pain/ OR Posture/ OR postur*.mp.)
9

14 **Screening and selection of studies**

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18 The citations retrieved from the above search were inserted into the reference
19 management software Endnote X7.4. Both authors independently scanned all the
20 titles and abstracts of the retrieved studies using the Rayyan systematic review web
21 app⁴⁷. Abstracts considered as potentially eligible were reserved for the
22 assessment of the full-text article. The citation lists of the potentially eligible papers
23 were screened for relevant studies. Any differences concerning eligibility after the full
24 text was evaluated were resolved through consensus. A record of reasons for
25 excluding studies was kept during the review process. The interrater agreement in
26 the screening and eligibility stages is reported using the Cohen's kappa coefficient
27 (κ).
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41 The inclusion and exclusion criteria are presented in Table 1. The PICO framework
42 was used for the question formulation, the search strategy and the reporting of the
43 inclusion and exclusion criteria.
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48 **Quality assessment**

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51 The quality of the included studies was assessed independently by both authors
52 using, the Effective Public Health Practice Project Quality Assessment Tool (EPHPP).
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54 This is a generic tool used to evaluate a variety of intervention study designs. It has
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3 been judged suitable to be used in systematic reviews of effectiveness and has been
4 reported to have content and construct validity ⁴⁸. The tool assesses six domains:
5 selection bias, study design, confounders, blinding, data collection method and
6 withdrawals/dropouts ⁴⁹. Each domain can be rated as strong (1 point), moderate (2
7 points), or weak (3 points) ⁴⁹. The EPHPP dictionary/guidance was followed to rate
8 each domain and provide a global judgment for each study. Any disagreement in the
9 ratings was resolved with discussion, and the interrater agreement is reported using
10 the Cohen's kappa coefficient (κ).
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20 21 **Data extraction and analysis**

22 Information extracted from the studies included target population and size, study
23 design, type of intervention, methods for assessment of MSD pain and posture,
24 outcomes reported and results. Data extraction was performed by one reviewer (AP)
25 and checked by the second reviewer (MBD) using a standard extraction table
26 developed a priori. Any disagreement was resolved by discussion and consensus.
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28 The findings from the included studies were synthesised using tables and a narrative
29 summary.
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40 41 **RESULTS**

42 43 **Search results**

44 The electronic searches yielded 526 results. After the duplicates were removed, 446
45 titles and abstracts were screened for relevance. From the 17 possibly relevant
46 papers eight met the inclusion criteria. The selection process for relevant studies and
47 the numbers at each stage are shown in Figure 1. No new studies were found after
48 screening the citation lists of the above 17 papers. The reasons for exclusion of the
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3 remaining nine studies at the full-text stage are presented in Table 2. The two
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5 reviewers demonstrated good ($\kappa=0.67$, 95%CI, 0.495 to 0.846 $p<0.005$) and very
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7 good agreement ($\kappa=0.883$, 95%CI, 0.661 to 1.000 $p<0.005$) at the screening and
8
9 eligibility stage respectively.
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11 12 **Study characteristics and quality assessment**

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15 From the included studies, four investigated the effect of loupes on posture^{50, 51} and
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17 musculoskeletal pain^{52, 53}, four the effect of saddle seats on posture^{36, 54-56} and one
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19 of the latter explored the combined effect of magnification and use of a saddle seat
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21 on posture³⁶. The main characteristics of the included studies are summarised in
22
23 Table 3, and the consensus ratings for the quality assessment (each domain and
24
25 global judgment) of all studies are presented in Table 4. The agreement between the
26
27 reviewers in the quality assessment stage was very good ($\kappa=0.88$, 95%CI, 0.769 to
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29 0.992 $p<0.005$). A description of the different outcome measure methods used within
30
31 the studies is given in Table 5. The study characteristics and results of the above
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33 studies are discussed in detail below.
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38 **Effect of loupes**

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40 All four studies used similar magnification (2.5x). Branson et al. used the “through
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42 the lense” type of loupes⁵⁰ while the other three used the flip-up design⁵¹⁻⁵³.
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47 Two of the studies employed a randomised within subjects design and investigated
48
49 the impact of loupes on dental hygiene students' posture^{50, 51}. The quality of the
50
51 studies was judged as moderate. The students were videotaped while performing a
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53 clinical task (periodontal probing⁵⁰ and scaling⁵¹) in a clinical setting. Their posture
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55 was assessed by Branson's Posture Assessment Instrument (BPAI). In both studies,
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3 when the students used the magnification loupes, they adopted significantly better
4 postures than when used traditional safety glasses ^{50, 51}. The students' experience
5 with the loupes was also reported in the above studies. The majority of the students
6 believed that the use of loupes improved their posture (100% and 78%), increased
7 their visual acuity (95% and 91%), and they were acceptable in terms of their weight
8 (95% and 94%) and the time required to adjust (90% and 71%) ^{50, 51}. During the
9 adjustment period vertigo (43% and 35%) and eye soreness (5% and 38%)
10 appeared to be the most prevalent symptoms ^{50, 51}.

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22 The other two studies by Hayes et al. adopted a pre-test post-test design with a non-
23 equivalent control group comparing musculoskeletal discomfort in dental hygienists
24 wearing loupes with final year dental hygiene students who did not wear loupes ^{52, 53}
25 in a non-simulated clinical environment. For the assessment of musculoskeletal
26 discomfort, self-reported validated survey data (DASH for the arm, shoulder and
27 hand symptoms ⁵² and the NPDS for the neck symptoms ⁵³) were collected before
28 and six months after the intervention. Within the test group, the DASH scores were
29 reduced indicating reduction in the reported discomfort, whilst in the control group an
30 increase in the DASH scores was observed ⁵². The mean DASH scores difference
31 between the test and control group was found statistical significant ⁵² favouring the
32 use of loupes. Contrary, no significant differences were observed in the NPDS
33 scores either within the test group or between the test and control group, indicating
34 that the dental hygienists wearing loupes did not perceive any improvements in
35 terms of their neck pain ⁵³. Outcomes of physical assessment of the participants
36 carried out by a physiotherapist were also reported. Improvements over time were
37 noted in the loupes-users for cervical range of motion and deep neck muscle
38 endurance ⁵³. Given the increased risk of selection bias and the use of a non-
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3 matched control group, the methodological quality of these two studies was judged
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5 weak.
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8 **Effect of saddle seats**

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11 Two of the studies evaluated the Salli™ saddle seat^{36, 54} and the other two the
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13 Bambach™ seat^{55, 56}. All of the studies explored the impact of the seats on posture,
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15 but none investigated their impact on musculoskeletal pain or incidence of MSDs.
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19 In two randomised between subject studies, preclinical dental students were
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21 observed while performing simulated dental tasks on phantom heads^{36, 55, 56}. Their
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23 posture was assessed by the RULA method as recorded in videotapes³⁶ or
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25 photographs^{55, 56} taken 15 minutes after the simulated task had commenced. Both
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27 studies found that the students who used the saddle seats adopted a more
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29 favourable posture than students who used the conventional seats. The difference in
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31 the RULA scores between the groups was found statistically significant^{36, 55, 56}. The
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33 quality of the above studies was judged as moderate. The same observational
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35 method (RULA) was used to assess the posture of practising dentists in their dental
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37 offices whilst treating patients⁵⁵. Similarly, dentists who used saddle seats were
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39 found to have a significantly improved posture than their peers who used
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41 conventional dental seats⁵⁵. Due to the study design (no randomisation), the quality
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43 of this study was judged as weak. The results of the above studies are reported in
44
45 Table 6. Lower RULA scores indicate a posture closer to the neutral posture and a
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47 lower risk of developing MSDs.
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53 Finally, De Bruyne et al., in a randomised within subjects study, used a wireless
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55 device (BodyGuard™) to evaluate the spinal posture of a convenient sample of
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57 dentists and dental students while performing a simulated dental screening task on a
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phantom head⁵⁴. This device measures the deviation of the spine from the neutral lumbar spine sitting posture, without taking into consideration the positioning of the upper limbs and neck. The findings of this study demonstrated that the participant dentists adopted a more favourable posture when seated in the saddle seats⁵⁴. In contrast, when they used the conventional seats, their posture was significantly more flexed and deviant from the neutral spinal posture⁵⁴. The methodological quality of this study, however, was judged overall weak.

Effect of saddle seats and magnification lenses

Dable et al. compared the posture among three groups of dental students who sit on a saddle seat and a conventional seat with and without back rest³⁶. Their posture was rated using the RULA method while performing dental procedures on a phantom head with or without magnification lenses³⁶. For all three groups, the students' posture was improved when used magnification. Amongst the six conditions, the best posture was achieved when the students used the saddle seat and magnification lenses conjunctively³⁶. The differences between and amongst groups were found highly statistically significant³⁶. The quality of the study was rated as moderate.

DISCUSSION

According to the available evidence, the use of an ergonomic saddle seat is beneficial in correcting the dental worker's posture by facilitating a neutral lumbar spine posture. Such a neutral posture is obtained through positioning the lower lumbar spine into slight anterior tilt and slight lumbar lordosis while relaxation of the thoracic spine is maintained⁵⁷. This posture is considered to be conducive to musculoskeletal health and prevent back pain³⁸. However, none of the included

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3 studies investigated the perceived benefits of the seats as regards to the relief of
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5 musculoskeletal pain.
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9 In the same lines, the use of magnification loupes appears to improve working
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11 posture and reduce shoulder pain. Nonetheless, an additive effect has been
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13 suggested to exist when a saddle seat and magnification lenses are used together.
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15 Anecdotally, the majority of the loupes manufacturers advise their clients that they
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17 should invest in a fiber-optic light which is added to the loupes or to a headgear to
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19 increase visual acuity^{45, 58-60}. These headlamps can increase the light levels to as
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21 much as four times the intensity of the traditional overhead dental light⁶⁰. As the light
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23 is mounted on the centre of the forehead, it is closely aligned with the visual path,
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25 making shadowing less likely^{58, 60}. It can be speculated that better vision will reduce
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27 extensive neck flexion or shoulder uplifting. However, the potential effect of the
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29 adjunctive use of illumination on posture or musculoskeletal pain has not been
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31 investigated as yet.
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35 Noteworthy, the use of loupes has been shown to improve the quality of dental care
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37 which may be an additional reason why a practising dental clinician may decide to
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39 incorporate this gadget in their armamentarium. The use of loupes by dental
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41 students while performing simulated dental procedures has been shown to decrease
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43 the number of errors by half⁶¹, improve the quality of cavity preparations⁶², and
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45 increase efficiency and pace of work⁶³. Use of loupes also enhances the accuracy of
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47 caries diagnosis and detection⁶⁴. However, magnification over 4.5X may lead to
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49 unnecessary overtreatment and modify the operator's decision-making behaviour
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51 significantly⁶⁵. On the other hand, surprisingly, use of loupes did not seem to have a
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53 significant impact on the size of the cavities and the number of iatrogenic damage to
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55 the adjacent teeth after cavity preparation by professional dentists^{66, 67}. The use of
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3 magnification is majorly advocated for endodontics due to the extremely restricted
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5 working field (pulp chamber). It has been suggested that 2.5x magnification
6
7 enhances the fine motor skills required for Endodontics ⁶⁸. Similarly, in an in vivo
8
9 clinical study endodontists located the MB2 canal in maxillary molars significantly
10
11 more often when they used magnification aids (microscope or loupes) than no
12
13 magnification. When the maxillary first molars were considered separately, the
14
15 frequency of MB2 canal detection for the microscope, dental loupes, and no
16
17 magnification groups was 71.1%, 62.5%, and 17.2%, respectively. No significant
18
19 difference was found between the use of microscope and dental loupes ⁶⁹. However,
20
21 two recent systematic reviews failed to identify any evidence to support that the use
22
23 or not of magnification devices affect endodontic treatment outcomes ^{70, 71}.
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28 **Limitations of included studies**

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31 Most of the included studies recruited participants from a convenient sample (e.g.
32
33 dental students) and the sample size among the studies was relatively small. The
34
35 methodological quality of the studies was considered moderate for four of them ^{36, 50,}
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37 ^{51, 56} and weak for the other four ⁵²⁻⁵⁵. None of the studies was rated as
38
39 methodologically strong due to the stringent criteria of the EPHPP guidance ⁴⁹.
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41 Namely, for a study to be rated as strong, none of the component ratings can be
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43 weak ⁴⁹. All of the studies rated as weak in the blinding component, as both the
44
45 participants and the outcome assessors were aware of the intervention and the
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47 purpose of the research. Therefore, the conclusions of the review should be
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49 interpreted with caution.
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54 Nevertheless, as the participants were aware of being observed, it is highly likely that
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56 they adopted a better posture than they would normally have while working. This
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3 change in behaviour, while observed, is known as the Hawthorne effect ⁷². Hence,
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5 the reported effect on postural change may have been underestimated in the
6
7 included studies.
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10 **Strengths and weaknesses of the review**

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12 The present systematic review was conducted according to the PRISMA guidelines.
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14 The inclusion of articles was determined using a predetermined protocol,
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16 independent assessment by two reviewers and a final consensus decision. A
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18 validated quality assessment tool (EPHPP) was used independently by the two
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20 reviewers. The interrater agreement of the reviewers was judged as good and very
21
22 good in all stages of the reviewing process. However, statistical pooling of the
23
24 individual study results was not appropriate owing to the small number of included
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26 studies and the variability in study design and outcome measures.
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32 **Recommendations for future research**

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34 Future well powered longitudinal randomised controlled studies based in a clinical
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36 dental setting are warranted. The population of the studies should include dental or
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38 dental hygiene students and practising dental professionals with different years of
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40 experience. This may allow for subgroup analysis to explore the effect of the timing
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42 of the intervention (early or later in a professional's career).
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47 Regarding the intervention, a multiple arm trial investigating the effect of saddle
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49 seats, magnification loupes with or without illumination and combination of the above
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51 will shed light to the best combination of the above ergonomic solutions. A
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53 comparator control group will be needed.
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3 As regards to the outcomes, a triangulation approach will overcome the issues of
4 blinding described above. The self-reported musculoskeletal pain should be
5 recorded before and after the intervention using standard validated questionnaires
6 covering the areas of the neck, shoulder, back and upper limbs. An example of such
7 a measure is the standardised Nordic questionnaire which includes general
8 questions about musculoskeletal complaints of nine anatomical areas as well as
9 work absenteeism and working restrictions resulting from these complaints ⁷³. For
10 the assessment of posture, observational methods such as RULA or BPAI could be
11 used in conjunction with objective methods such as kinematic analysis. Use of
12 objective measures would reduce the risk of detection bias. An example of kinematic
13 analysis is the CUELA (computer-assisted acquisition and long-term analysis of
14 musculoskeletal loads) system ⁷⁴. The CUELA system uses sensors to record and
15 analyse body postures and it has been used in dental studies to measure the
16 posture of dentists during their normal working day ^{74, 75}. In addition, a physical
17 examination of the participants by a registered physiotherapist, as done by Hayes et
18 al. to assess the extent and severity of any musculoskeletal disabilities and disorders
19 will complement the reporting of these studies ^{52, 53}. This triangulation method of
20 evaluation is paramount for providing solid evidence for the effectiveness of the
21 preventive measures (seats and loupes) under investigation.
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45 46 **Implications for practice and education**

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49 Given the fact that musculoskeletal symptoms appear as early as the undergraduate
50 years ⁷⁶⁻⁷⁹, these preventive measures may be worth being introduced in the
51 undergraduate clinical training environment. However, such an implementation
52 should be accompanied by comprehensive theoretical and practical ergonomics
53 training. Most undergraduate dental and dental hygiene curricula, in this day and age,
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3 include a taught component about basic principles of ergonomics (patient and
4 operator positioning). Knowledge of correct positioning alone has not been found
5 sufficient to improve the student's posture⁸⁰⁻⁸². One of the major reported obstacles
6 in applying ergonomic knowledge is poor visualisation⁸⁰. Therefore, use of loupes
7 early in the preclinical training may address this issue and facilitate correct working
8 postures. Besides, the paucity of more holistic ergonomics education including early
9 detection of musculoskeletal disorders, appropriate seating selection, preventive
10 strategies and exercises has been identified, and it is critical to be addressed in
11 modern undergraduate, postgraduate and continuing education curricula activities^{78,}
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Nonetheless, the accumulating evidence in the dental literature indicates that the modern dental hygienists and therapists may benefit from using an ergonomic saddle seat and loupes as their posture and comfort concerned. Although the cost of loupes and ergonomic saddle seats is relatively high, the potential long-term benefits may outweigh the initial high cost of purchase.

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Figure and Table Legends

Figure 1: PRISMA Flowchart: Identification and selection process of studies

Table 1: Inclusion and exclusion criteria

Table 2: Excluded studies

Table 3: Characteristics of the included studies

Table 4: Quality assessment of the included studies

Table 5: Description of outcome measures used in the included studies

Table 6: Effect of saddle seats on posture (RULA scores)

Figure 1: PRISMA flowchart: Identification and selection process of studies

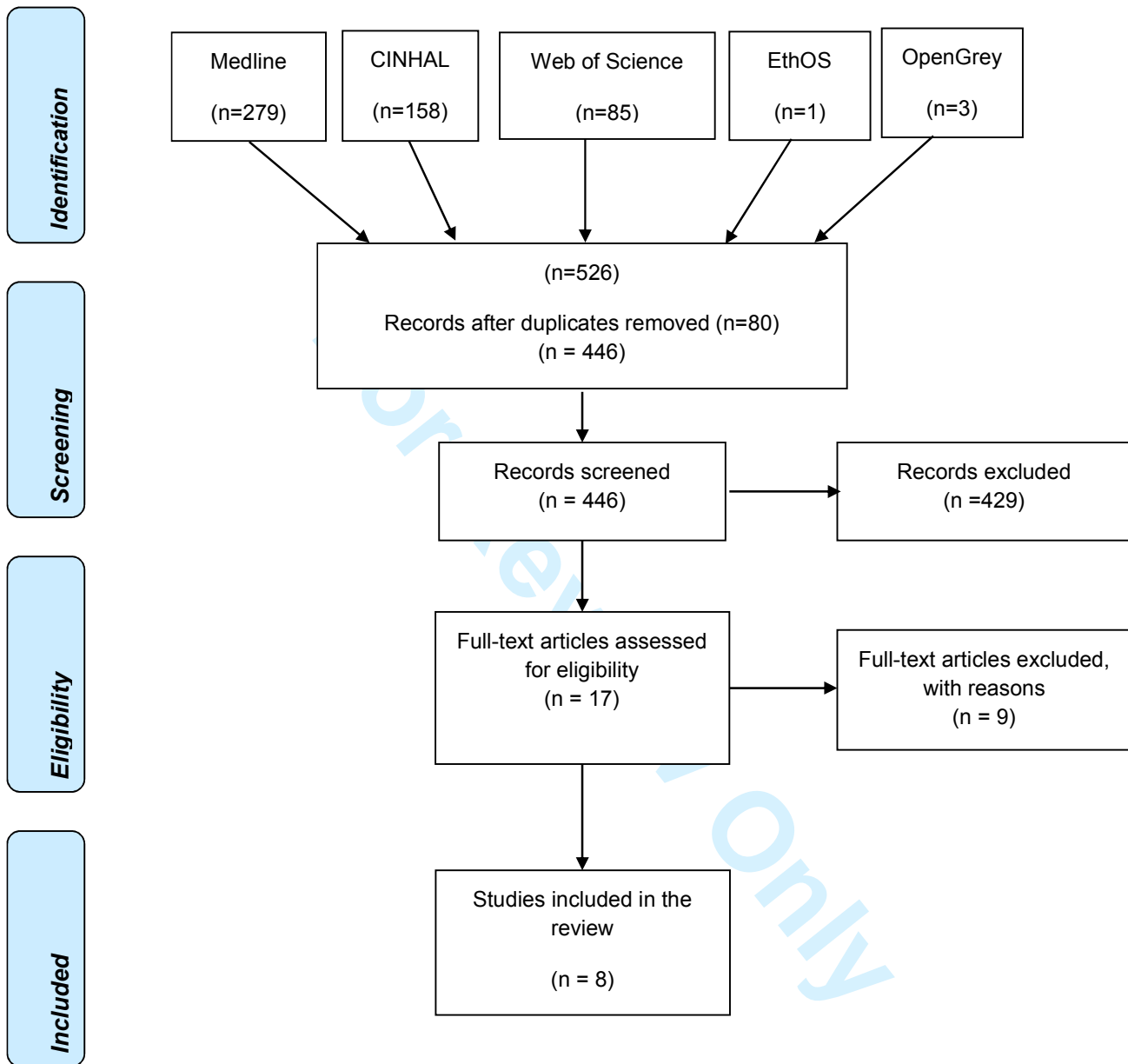


Table 1: Inclusion and exclusion criteria

	Inclusion Criteria	Exclusion Criteria
P (Population)	<ul style="list-style-type: none"> Dental care professionals who deliver dental treatment directly (dentists, dental students, dental hygienists, dental therapists, dental hygiene and therapy students) 	<ul style="list-style-type: none"> Dental care professionals who do not deliver dental treatment directly (dental nurses, dental technicians, receptionists, auxiliary staff) Other healthcare professionals (doctors, surgeons, nurses, etc.)
I (Intervention)	<ul style="list-style-type: none"> Use of saddle seats in a simulated dental or clinical setting or Use of magnification loupes when performing a simulated or life-case dental procedure 	<ul style="list-style-type: none"> Use of other types of ergonomic seats than saddle seats or Use of lenses which do not offer magnification
C (Comparison)	<ul style="list-style-type: none"> Conventional dental seat Conventional lenses (no magnification) or safety glasses 	<ul style="list-style-type: none"> Studies which have not used a comparator group.
O (Outcome)	<ul style="list-style-type: none"> musculoskeletal pain (using a validated measure e.g. VAS or validated questionnaire) MSD prevalence or incidence Change in posture (using a validated assessment method) 	<ul style="list-style-type: none"> Muscle activity or EMG readings as this information is hard to be translated into clinical practice
s (Study Type)	Prospective prospective studies: <ul style="list-style-type: none"> Randomised controlled trials Crossover studies Pre and Post-test studies Cohort studies 	<ul style="list-style-type: none"> Non-experimental studies Studies with no comparator group Surveys Opinion pieces Reviews

Table 2: Excluded studies

	Citation	Reason for exclusion
1	Haddad, O., Sanjari, M.A., Amirfazli, A., Narimani, R., and Parnianpour, M. (2012): Trapezius muscle activity in using ordinary and ergonomically designed dentistry chairs. <i>International Journal of Occupational & Environmental Medicine</i> 3,76-83.	Only muscle activity was assessed.
2	Hayes, M.J., Taylor, J.A., and Smith, D.R. (2012): Predictors of work-related musculoskeletal disorders among dental hygienists. <i>International Journal of Dental Hygiene</i> 10,265-269.	Cross-sectional study (survey).
3	Khan, S.A., and Yee Chew, K. (2013): Effect of working characteristics and taught ergonomics on the prevalence of musculoskeletal disorders amongst dental students. <i>BMC Musculoskeletal Disorders</i> 14,118-118.	Cross-sectional study (survey) Not intervention of interest
4	Lindegard, A., Gustafsson, M., and Hansson, G.A. (2012): Effects of prismatic glasses including optometric correction on head and neck kinematics, perceived exertion and comfort during dental work in the oral cavity--a randomised controlled intervention. <i>Applied Ergonomics</i> 43,246-253.	The prismatic glasses did not offer magnification.
5	Nesbitt-Sceviour, D. (2006): Operator stools: Correct posture through technology and selection. <i>Contemporary Oral Hygiene</i> 6,8-10.	Review
6	Strassler, H.E. (1990): Magnification systems improve quality and posture. <i>Journal of Esthetic Dentistry</i> 2,183-184.	Review
7	Valachi, B.S. (2008): Operator stools: How selection and adjustment impact your health. <i>Dentistry Today</i> 27,148, 150-141.	Review
8	Westley, H. (2013): An overview of saddle seats and their benefits in dentistry. <i>Dental Nursing</i> 9,584-587.	Review
9	Woo, G.C., and Ing, B. (1988): Magnification devices for the presbyopic dentist. <i>Journal of the Canadian Dental Association</i> 54,447-449.	Review

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Table 3: Characteristics of the included studies

Authors/ Date	Study design	Population	Outcome measure /Method	Results	Quality Assessment
Loupes					
Branson et al., 2004	Randomised within-subjects design	Final year dental hygiene students (n=19)	Posture (BPAI)	Posture was more acceptable with loupes than wearing traditional safety glasses. Mean difference in BPAI scores: 2.97 (p=0.019).	Moderate
Hayes et al., 2014	Pre-test post-test, between subjects design	Dental hygienists (n= 12) and final year dental hygiene students (n=17)	Pain (DASH)	Improvement of DASH scores in the test group. Worsening of symptoms in the control group over time. Mean difference in pre-post test scores in test group (3.39) vs control group (-1.59) (p=0.037).	Weak
Hayes et al., 2016	Pre-test post-test, between subjects design	Dental hygienists (n= 12) and final year dental hygiene students (n=17)	Pain (NPDS)	Loupes created no significant difference in neck pain (NPDS score).	Weak
Maillet et al., 2008	Randomised within-subjects design	First-year dental hygiene students (n=35)	Posture (BPAI)	Significant improvement in posture. Mean difference in BPAI scores: 4.4 (p<0.001)	Moderate
Saddle seats					
Dable et al., 2014	Randomised between subjects design	90 second year dental students (3 groups, n=30 each)	Posture (RULA)	Improved posture with saddle seat (p=0.001).	Moderate
De Bruyne et al., 2016	Randomised within subjects design)	Dentists (n=25)	Posture (BodyGuard™)	Spinal posture was significantly more flexed than the saddle seat (p=0.014)	Weak
Gandavadi et al., 2007 & Gandavadi, 2008	Randomised between subjects design	60 second year dental students (2 groups, n=30 each)	Posture (RULA)	Significantly better posture in Saddle seat group (p<0.01).	Moderate
Gandavadi, 2008	Non-randomised between subjects	22 dentists (2 groups: saddle seats n= 12, conventional seats n=10)	Posture (RULA)	Significantly better posture in Saddle seat group(p<0.01).	Weak
Loupes and saddle seats					
Dable et al., 2014	Randomised between subjects design	90 second year dental students (3 groups, n=30 each)	Posture (RULA)	Posture was significantly better for the group of students who used saddle seats and magnification lenses (p<0.01).	Moderate

For Review Only

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Table 4: Quality assessment of the included studies

Intervention	EPHPP QA domains							
	Authors/Date	Selection Bias	Study design	Confounders	Blinding	Data Collection Method	Withdraw and Dropouts	GLOBAL JUDGMENT
Loupes	Branson et.al.,2004	2	1	1	3	1	1	Moderate
	Hayes et al., 2014	2	2	3	3	1	1	Weak
	Hayes et al.,2016	2	2	3	3	1	1	Weak
	Maillet et al., 2008	2	1	1	3	1	1	Moderate
Saddle seats	Dable et al., 2014	1	1	1	3	1	1	Moderate
	De Bruyne et al.,2016	3	2	1	3	1	1	Weak
	Gandavadi et al., 2007 & Gandavadi, 2008	1	1	2	3	1	1	Moderate
	Gandavadi, 2008	2	3	3	3	1	1	Weak
Loupes and saddle seats	Dable et al., 2014	1	1	1	3	1	1	Moderate

1= Strong, 2=Moderate, 3=Weak

Table 5: Description of outcome measures used in the included studies

Outcome measures for assessment of pain		
DASH	Disabilities of Arm shoulder and Hand	This questionnaire measures symptoms in the arm, shoulder and hand and the participants' ability to perform certain activities. It consists of 30 questions that require a response on a Likert scale.
NDPS	Neck Pain Disability Scale	This survey measures neck pain and dysfunction. It consists of 20 questions which require the subject to respond in a visual analogue scale (VAS)
Outcome measures for postural assessment		
BPAI	Branson's Postural Assessment Instrument	This instrument provides a mean for measuring posture outside ideal ranges. During a five-minute period, the evaluator examines ten components of the body posture and then using established criteria, rates the posture as acceptable, compromised or harmful. A weighted composite score is then computed such the final score represents posture impact over the five-minute time frame.
RULA	Rapid Upper Limb Assessment	This tool provides a quick assessment of postures of the neck, trunk, and upper limbs along with muscle function and the external loads experienced by the body. The method uses diagrams of body postures and three scoring tables to provide an evaluation of exposure to risk factors. A risk score is attributed to each of these regions based on their angular deviation from the neutral posture. A final score (grand score) is calculated after taking into account the muscular activity and exerted forces and ranges from 1 to 7.
BodyGuard™		This method uses a wireless device to evaluate spinal posture. It incorporates a strain gauge which gives information about the relative distance between anatomical landmarks. The amount of flexion or extension of the lumbar spine is derived from the degree of strain gauge elongation.

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Table 6: Effect of saddle seats on posture (RULA scores)

Author/Year	Sample			RULA Score			P value
	Saddle Seat	Conventional		Saddle Seat	Conventional		
Gandavadi et al. (2007)	30 dental students	30 dental students		2.80(R) , 2.66(L)	5.06(R), 5.03(L)		p<0.01
Gandavadi (2008)	12 dentists	10 dentists		2.50(R), 2.75(L)	3.40(R), 3.90(L)		(R): p=0.005 (L): p=0.016
	Saddle Seat	CC1	CC2	Saddle Seat	CC1	CC2	P value
Dable et al. (2014)	30 dental students	30 dental students	30 dental students	2.73	6.57	6.96	p=0.001

**CC1: Conventional chair with back rest, CC2: Conventional chair without back rest
(R): Right, (L): Left**