

Influence of different stool types on muscle activity and lumbar posture among dentists during a simulated dental screening task

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Abstract

Whereas in the past dental stools typically facilitated a 90° hip angle, a number of currently available alternative designs allow for a more extended hip posture. The present study investigated the influence of different stool types on muscle activity and lumbar posture. Twenty five participants completed a simulated dental procedure on a standard stool, a saddle and the Ghopec. The latter stool comprises a seat pan consisting of a horizontal rear part for the pelvis and an inclinable sloping down front part for the upper legs, with a vertically and horizontally adjustable back rest. Lumbar posture was most close to neutral on the Ghopec, whereas sitting on a standard/saddle stool resulted in more flexed/extended postures respectively. Sitting with a 90° angle (standard stool) resulted in higher activation of back muscles while sitting with a 125° angle (saddle and Ghopec) activated abdominal muscles more, although less in the presence of a backrest (Ghopec). To maintain neutral posture during dental screening, the Ghopec is considered the most suitable design for the tasks undertaken.

Keywords: dental ergonomics, posture, sitting, muscle activity

1 Introduction

1.1 Musculoskeletal disorders in dentistry

Oral health care providers are vulnerable to work-related musculoskeletal disorders (MSDs) (Hayes et al., 2009; Leggat et al., 2007; Puriene et al., 2007; Yamalik, 2007) and female oral health care workers seem to be even more susceptible to these MSDs than their male colleagues (Hayes et al., 2009; Puriene et al., 2007). Prevalence numbers of general musculoskeletal pain between 64 and 93% have been documented and regions most often affected in dentists were found to be the back (36.3-60.1%) and the neck (19.8-85%) (Hayes et al., 2009), whereas musculoskeletal pain affects between 13.5 and 47% of the general population (Cimmino et al., 2011).

Despite technical advances in dentistry, occupational health problems persist (Leggat et al., 2007). Repeated non-neutral, deviated or inadequate working postures, forceful hand movements, inadequate equipment and workplace designs and inappropriate workplace patterns have been identified as risk factors for occupational health problems in dentistry (Rucker & Sunell, 2002; Valachi & Valachi, 2003; Yamalik, 2007). MSDs have also been associated with prolonged static postures, as overall dynamic loads are low in dentistry (Leggat et al., 2007).

1.2 Sitting

To avoid potentially painful end-range positions and to facilitate activation of trunk muscles during sitting, the potential benefits of neutral lumbar spine postures have been emphasized (O'Sullivan et al., 2012). 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 maintained (O'Sullivan et al., 2010). In practice, habitual sitting postures have been found to be more flexed than neutral sitting posture (O'Sullivan et al., 2010). Nevertheless it appears that pain-free subjects can reliably assume a neutral sitting posture when asked (O'Sullivan et al., 2010).

Attaining a neutral spine can be reached in an active way when trunk muscles are engaged (Bendix et al., 1996). However, this position is hard to maintain on most chairs and the lumbopelvic musculature in pain-free subjects has been found to be more active while maintaining an optimally aligned, erect posture compared to passive postures (O'Sullivan et al., 2002) – effectively meaning that 'good' seated postures require more effort than 'poor' postures. To solve the latter problem a lumbar support (to facilitate lumbar lordosis) or an increase in hip angle (to raise anterior pelvic tilt) is often suggested (Bendix et al., 1996; Michel & Helander, 1994). However, if the backrest is not pushed toward the lower back, kyphosis of the lumbar spine might occur when the trunk is stabilized against the backrest (Bendix et al., 1996). To accommodate an open hip angle, a tilted seat pan with a gripping surface or a seat with a horizontal rear portion to accommodate the ischial tuberosities and a sloping front part supporting the upper legs is needed, followed by an increase in seat height to allow forward and downward inclination of the upper legs (Corlett, 1999; Mandal, 1981). Without the horizontal rear part there is a risk of sliding forward on a downward sloping seat. Compared to sitting on a conventional chair, this way of sitting was found to result in more anterior tilt of the pelvis and increased lordosis (Bridger, 1988; Bridger et al., 1989).

Dentists most of the time sit during work and sitting is considered an aggravating factor in lower back pain (O'Sullivan et al., 2010). Conventional sitting results in flattening of the lumbar curve, posterior

tilt of the pelvis and increased low back compressive loads (Adams et al., 2007; Callaghan & McGill, 2001; Harrison et al., 1999; Keegan, 1953). Upright sitting (i.e. neutral posture) is associated with high muscle activity, which during prolonged sitting has been associated with muscle fatigue and pain (Grooten et al., 2013). Conversely, slump sitting has been associated with increased spinal loading due to the posterior tilt of the pelvis which is then counterbalanced by excessive contractions of the dorsal spinal muscles (Grooten et al., 2013). Slump sitting has also been associated with greater head/neck flexion, anterior translation of the head and increased cervical erector spinae muscle activity in comparison with upright sitting (Caneiro et al., 2010). Due to the nature of dental work, in which the working field is often hard to reach, maintaining a neutral posture during work is difficult. Despite clear recommendations concerning working posture (Hokwerda et al., 2006; Skovsgaard, 2013), high risk level postures related to neck and lower back pain have been found in dentists (Rafeemanesh et al., 2013).

Outside dentistry, it has been shown that sitting posture influences trunk muscle activation and spinal-pelvic curvature (O'Sullivan et al., 2006) and chairs inducing different sitting postures have been associated with differences in trunk muscle activation and lumbar flexion (O'Sullivan et al., 2012b). Standard dental stools allow an angle of 90° for both the hips and the knees. With a view to reduce back problems by promoting lumbar lordosis, standard stools found in dentistry are regularly replaced by stools that allow for a larger trunk-to-thigh angle. Among these are the saddle stools which most often are available without lumbar support. The use of a saddle seat, which leads to greater trunk-to-thigh angles, has been shown to reduce posterior rotation of the pelvis and consequently to facilitate the maintenance of a lumbar lordosis (= natural curve of the spine) (Gadge & Innes, 2007). The Ghopec (Gaining Height on Professional Ergonomic Chair) (JPG Ergonomics, Utrecht, the Netherlands) is another chair which can be adjusted to a larger trunk-to-thigh angle.

1.3 Aim

Both saddle stools and Ghopec chairs are available in dentistry, but until now no data have been published on their use in dentistry and it is unclear if indeed the chairs have the positive effect, suggested by their manufacturers, on muscle activity and lumbar posture during dental tasks. Therefore the purpose of the present study is to evaluate the influence of different stool types on muscle activity and lumbar posture in dentists during work, and to answer the following questions:

- During dental work, does sitting on a dental stool, which induces a trunk-to-thigh angle larger than 90°, result in different activity of muscles contributing to this sitting posture compared to sitting on a standard dental stool?
- During work, does sitting on a dental stool, which induces a trunk-to-thigh angle larger than 90°, result in less flexion of the lumbar spine compared to sitting on a standard dental stool?

2 Materials and methods

2.1 Study design

A one-session within subjects study was performed. During this study, dentists/dental students performed a 15-min simulated dental screening on a phantom head, i.e. a fake head used for dental training, whilst sitting on 3 different stools. Each participant completed the same protocol except for the order in which they used the different stools. The combination of 3 different stools resulted in 6

possible sequences. Each participant blindly selected a paper with the sequence from a pile of turned-down papers. Differences in muscle activation and lumbar posture between the 3 dental stools were evaluated. Independent variables were dental stool type and dependent variables muscle activation and lumbar posture.

Ethical approval was obtained from the independent Commission for Medical Ethics of the University Hospital Ghent (B670201317498) and the University of Derby and all participants received an information letter after which they signed an informed consent form.

2.2 Participants

In total 25 participants, 8 male and 17 female, were recruited from the dentists (n=15) and dental students (n=10) at Ghent University (Hospital) on a voluntary basis. Participants were pain-free at the time of the investigation, aged > 18 years and not pregnant. They had a Body Mass Index from 18 to 25 and could speak/understand Dutch. People with persistent lower back pain in the last 2 years, previous spinal surgery or currently on pain medication were excluded. Also people with a pacemaker or people smaller than 5th percentile female (1.53 m) or taller than 95th percentile male (1.89 m) were excluded, the latter because average chair design is based on the principle 'design for all', which excludes these ranges. To make sure all participants were familiar with the screening task, only fourth- and fifth-year dental students and graduated dentists were selected.

The participants' mean (SD) age was 24.5 (3.9) years, body mass was 64.2 (7.9) kg, height was 170.4 (6.7) cm and body mass index was 22.1 (2.1) kg/m². Two participants were left-handed, the other 23 were right-handed.

All data on participants were obtained by self-report.

2.3 Materials

2.3.1 Experimental conditions

Data were collected for 3 different types of stool: a standard dental stool allowing an angle of 90° for both the hips and the knees and 2 alternative designs allowing a larger angle. As a standard dental stool the A-dec Doctor's stool, type 1601 without tilt feature, (Fig. 1a: A-dec, Newberg, Oregon, USA) was selected. The first of the alternative designs was a two-part saddle stool without back rest (Fig. 1b: Salli MultiAdjuster, Rautalampi, Finland). The second one was a stool with a seat pan consisting of a horizontal rear part for the pelvis and an adjustable sloping down front part for the legs, and a vertically and horizontally adjustable lumbar support (Fig. 1c: Ghopec Junior, JPG Ergonomics, Utrecht, the Netherlands).



Fig. 1a: A-DEC DOCTOR'S STOOL, **b:** SALLI MULTIADJUSTER, **c:** GHOPEC JUNIOR

2.3.2 Muscle activation

The activation of 7 muscles was analysed by means of sEMG. Measurements were performed using the Noraxon Myosystem (Myosystem 1400, Noraxon Inc., Scottsdale, AZ). All raw sEMG signals were bandpass-filtered and pre-amplified with an overall gain of 1000 and rejection ratio of 115 dB. The signals were converted at 1000 Hz and stored. The muscles studied were latissimus dorsi (LD), iliocostalis lumborum thoracic part (ICLT), multifidus (MF), gluteus maximus (GM), rectus femoris (RF), internal abdominal oblique (IO) and external abdominal oblique (EO). To obtain stable electrode contact and low skin impedance, prior to the experimental phase, skin preparation was performed for each subject as follows. After shaving excess hair, the skin was rubbed with ether to reduce skin impedance. Pairs of disposable wet gel Ag/AgCl surface electrodes (BlueSensor N, Ambu, Ballerup, Denmark) were attached to the skin with an inter-electrode distance of 30 mm, parallel to the muscle fibre direction bilaterally. Electrodes were placed 30mm lateral and caudal to the inferior angle of the scapula (LD), above and below the L1 level midway between the midline and the lateral aspect of the body (ICLT), lateral to the midline of the body above and below a line connecting the left and right posterior superior iliac spine (MF), midway between tuber ischiadicum and posterior superior iliac spine (GM), midway between the upper side of the patella and the anterior superior iliac spine (RF), midway between the anterior iliac spine and symphysis pubis above the inguinal ligament (IO), and 15 cm lateral to the umbilicus (EO) (Bouillon et al., 2012; Danneels et al., 2002; Danneels et al., 2001). A common earth electrode was placed over the angulus inferior of the scapula (Fig. 2).

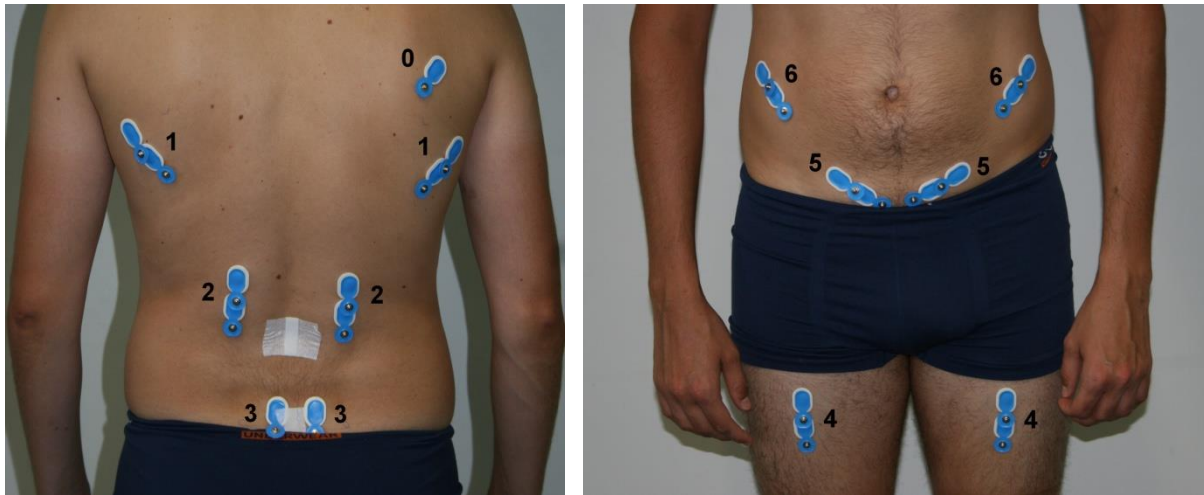


Fig. 2: ELECTRODE PLACEMENT FOR EARTH ELECTRODE = 0; LATISSIMUS DORSI = 1; ILIOCOSTALIS LUMBORUM THORACIC PART = 2; MULTIFIDUS = 3; RECTUS FEMORIS = 4; INTERNAL ABDOMINAL OBLIQUE = 5; EXTERNAL ABDOMINAL OBLIQUE = 6.

2.3.3 Lumbar posture

To evaluate the lumbar spinal posture in the sagittal plane the BodyGuard™ was used. BodyGuard™ (Sels Instruments, Vorselaar, Belgium) is a wireless method to evaluate spinal posture. It incorporates a strain gauge which gives information about the relative distance between anatomical landmarks. The amount of flexion/extension of the lumbar spine is derived from the degree of strain gauge elongation.

BodyGuard™ is a relatively new device to evaluate lumbo-pelvic posture. BodyGuard™ was validated against a traditional flexible electrogoniometer (O'Sullivan et al., 2011) and correlation was found to be high in both sitting ($r=0.98$) and standing ($r=0.99$). Excellent association for between-day ($ICC \geq 0.84$) and inter-rater reliability ($ICC \geq 0.91$) was found and reliability was evaluated as good as, or better than the other devices (O'Sullivan et al., 2011). Lumbo-pelvic posture during functional tasks and postures (sitting and standing) was measured using BodyGuard™ and a traditional laboratory-based motion analysis system and the results compared (O'Sullivan et al., 2012). The results support the concurrent validity of BodyGuard™ (mean difference between measures 0.25° to 5.8° for sitting, 0° to 6.2° for standing). To evaluate whether BodyGuard™ reflects the underlying vertebral alignment and motion, comparison with videofluoroscopy was also performed. Strong correlation was found between the results of both methods ($r=0.94$ for sitting, $r=0.88$ for standing) (O'Sullivan et al., 2012b). Of course absolute agreement between the skin-mounted posture monitor and measurement of underlying vertebral posture and motion is not possible. Nevertheless the results suggest the validity of BodyGuard™ is at least similar to that of other posture monitors.

The spinal levels of L3 and S2 were palpated and the strain gauge was positioned and fixed directly over the spine at these levels. As such the gauge was slightly pre-stressed in a neutral lumbar spine sitting posture. To calibrate the posture monitor, participants were positioned on a standard dental stool in a trunk-to-thigh angle of 90° and guided in to a neutral lumbar spine sitting posture by manual and verbal facilitation (zero point). This neutral posture was obtained through positioning the lower lumbar spine into slight anterior tilt and slight lumbar lordosis while maintaining relaxation of

the thoracic spine (O'Sullivan et al., 2010). Next, from this position, the participants were guided into 25° forward trunk lean which was considered the calibration point. The zero and calibration point being set, the degree of flexion/extension can be calculated by the posture monitor based on the elongation of the strain gauge. Postural data were recorded at 20Hz.

2.4 Procedure

Participants were positioned at a simulated workstation of adjustable height with an operating lamp, phantom head and a dental model. The ideal working distance (a distance between 30 and 40 cm at which the participant had the clearest view and measured from the eye to a fixed point on the phantom head) was then defined. This distance was kept throughout the 3 different testing conditions. In order to exclude any influences from differences in shoes (height of heels) they were barefoot. With the feet flat on the floor and the lower legs perpendicular to the floor, the standard stool was adjusted until the hip and knee joints reached an angle of 90° and the lumbar spine was in a neutral position. Both other stools were adjusted to 125° knee and hip angle. Next the back rests of the standard and Ghopec stool were adjusted in the vertical and horizontal plane until contact with the iliac crest was reached, and the height of the phantom head was adjusted to each stool. As the sitting height varied according to the stool, the height of the phantom head had to be adjusted to maintain the ideal working distance on each stool. Participants were blinded as to when sEMG and posture measurements were recorded. They completed a standardized dental screening task with a break of 5 minutes between stools during which time participants did not sit down and stools were changed.

The phantom head was rolled in front of the participants and they performed the same dental screening task for 15.5 minutes on each stool (lower right/left quadrant of the mouth for respectively right-/left-handed dentists). Electromyography data were recorded at 0, 5, 10 and 15 minutes for 30 seconds and posture monitoring was performed throughout the complete 15.5 minutes.

2.5 Data processing

2.5.1 Muscle activation

The raw 30 seconds of sEMG data from all testing periods were processed. Whenever measuring near the heart, electrocardiographic bursts may contaminate the sEMG recording. Therefore electrocardiographic reduction of the stored data was performed. The data were full wave rectified and smoothed with a root mean square with a window of 100 milliseconds. Noraxon MyoResearch XP 1.08.32 software was used to analyze the data from the 4 testing periods together. This resulted in a mean amplitude per muscle per stool.

2.5.2 Lumbar posture

Postural data were analyzed for the complete 15.5 minutes per dental stool for each participant. This allowed for the production of a mean posture score, calculated from the recorded data.

2.6 Statistical analysis

Statistical analysis was performed through IBM SPSS Statistics 19. For all statistical tests, the level of significance was set at $\alpha = 0.05$. Normality was analyzed using Shapiro-Wilk tests.

As the sEMG results for several muscles did not meet the assumptions for ANOVA, non-parametric tests were used for evaluation. For comparison of the sEMG results of each muscle between the 3

stools Friedman tests were adopted. If significance was present, pairwise comparisons were performed using Wilcoxon signed rank tests after which a Bonferroni correction was administered.

Except for sphericity, the average posture results produced by the BodyGuard™ met the assumptions for ANOVA. Consequently the parametric one-way repeated measures ANOVA with Greenhouse-Geisser correction was selected to evaluate the results, and post hoc pairwise comparisons were performed with Bonferroni correction.

3 Results

3.1 Muscle activation

The overall results for muscle activation on the 3 stools are illustrated in Table 1.

Significant differences were found for right ICLT and left ICLT, right IO and left IO and for left EO . Muscle activity in right ICLT was significantly higher on the standard stool than on the saddle and Ghopec stool, in left ICLT higher on the standard than on the saddle stool. In both right and left IO muscle activity was significantly higher on the saddle stool than on the Ghopec stool. Also muscle activity on the Ghopec stool was higher than on the standard stool. Muscle activity of the left EO was significantly higher on the saddle than on the standard stool.

The p-values and effect sizes (Coolican, 2009) of pairwise comparisons are illustrated in Table 2.

Table 1: MEDIAN MUSCLE ACTIVITY AND RANGE (IN μV) OF THE DIFFERENT MUSCLES DURING A PERIODONTAL SCREENING TASK ON THE STANDARD, SADDLE AND GHOPEC STOOL.

	LD right		ICLT right		MF right		GM right		RF right		IO right		EO right	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Standard	7.4	4.1-14.7	18.6	8.6-48.7	7.9	3.0-32.0	1.9	1.4-5.0	2.0	1.3-27.4	3.3	2.0-11.8	4.0	1.9-8.9
Saddle	6.2	3.4-15.4	10.5	2.4-35.8	5.5	2.3-21.3	1.9	1.5-4.2	2.5	1.5-7.3	5.7	1.8-20.0	4.0	2.1-9.9
Ghopec	6.0	3.2-21.0	13.2	4.9-35.7	6.7	3.2-55.4	1.9	1.5-3.2	2.9	1.4-10.9	4.0	1.9-9.4	4.3	2.6-7.3
p-value	0.075		<0.001		0.094		0.956		0.344		<0.001		0.422	

	LD left		ICLT left		MF left		GM left		RF left		IO left		EO left	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Standard	4.2	2.9-11.2	14.6	5.8-35.3	7.0	2.7-33.7	1.9	1.3-4.0	2.8	1.6-18.8	3.8	1.8-7.7	3.9	2.2-6.6
Saddle	4.7	2.9-10.4	10.2	2.7-32.3	6.5	2.1-26.5	1.9	1.3-5.2	3.0	1.6-8.3	6.5	1.7-18.8	5.1	2.3-13.4
Ghopec	4.0	2.8-12.2	13.8	4.7-32.8	6.3	3.1-22.2	1.7	1.3-5.7	3.8	1.5-9.9	4.5	1.8-9.6	3.6	2.2-8.0
p-value	0.422		0.012		0.113		0.405		0.444		<0.001		0.012	

D = latissimus dorsi; ICLT = iliocostalis lumborum thoracic part; MF = multifidus; GM = gluteus maximus; RF = rectus femoris; IO = internal abdominal oblique; EO = external abdominal oblique

Table 2: P-VALUES AND EFFECT SIZES (R) OF PAIRWISE MUSCLE ACTIVATION COMPARISONS WITH SIGNIFICANT DIFFERENCE.

Muscle	Side	Significant difference	p-value	r-value	Effect size
ICLT	Right	Standard > Ghopec	0.009	0.45	Moderate
		Standard > Saddle	<0.001	0.59	Large
	Left	Standard > Saddle	0.015	0.41	Moderate
IO	Right	Saddle > Ghopec	0.003	0.48	Moderate
		Ghopec > Standard	0.024	0.4	Moderate
		Saddle > Standard	<0.001	0.59	Large
	Left	Saddle > Ghopec	0.021	0.4	Moderate
		Ghopec > Standard	0.003	0.5	Large
		Saddle > Standard	<0.001	0.57	Large
EO	Left	Saddle > Standard	0.012	0.44	Moderate

ICLT = iliocostalis lumborum thoracic part; IO = internal abdominal oblique; EO = external abdominal oblique

3.2 Lumbar posture

The overall results for lumbar posture on the 3 stools are illustrated in Table 3.

A significant difference in lumbar flexion between the 3 stools was found ($p=0.003$). The effect size was large, $\eta^2=0.291$ (Coolican, 2009). Whereas flexion on the Ghopec stool was close to zero (= neutral posture), the value for lumbar posture on the saddle stool was negative (i.e. an extended posture). Flexion on the saddle stool was significantly lower than on the Ghopec ($p=0.022$). Posture on the standard stool was more flexed than on the other 2 stools, but only significantly higher than on the saddle stool ($p=0.014$).

Table 3: MEAN LUMBAR POSTURE AND STANDARD DEVIATION, MINIMUM, MAXIMUM AND RANGE ($^{\circ}$ FLEXION) DURING A PERIODONTAL SCREENING TASK ON THE STANDARD, SADDLE AND GHOPEC STOOL. (0° , POSITIVE AND NEGATIVE VALUES RESPECTIVELY MEAN NEUTRAL POSTURE, FLEXION AND EXTENSION)

	Standard	Saddle	Ghopec
Mean	4.4 ^a	-5.7 ^b	1.0 ^a
(SD)	8.1	16.4	10.0
Minimum	-12.9	-38.4	-21.1
Maximum	19.6	35.9	13.4
Range	32.5	74.3	34.5

Mean values marked with the same superscript letter were not statistically different from each other

4 Discussion

The aim of the present study was to evaluate the influence of different stool types on muscle activity and lumbar posture in dentists during work. The results indicate that, under the conditions of the present study, during a 15 minute dental screening task, pain-free dentists or dental students on a saddle stool, sat in less lumbar flexion (-6°) than on the standard (4°) or Ghopec (1°) stool. This means a difference of 10° between the average most flexed and most extended position. Whereas muscle activity in the ICLT was higher when sitting on the standard stool compared to sitting with a larger trunk-to-thigh angle, abdominal muscles were less active.

In order to avoid confounding variables as much as possible, exclusion criteria were strict. Only dentists and dental students were selected to participate in the trial. More females than males participated in the present study. This reflects the changing gender profile of the dental profession. As it has been observed that female oral health workers are more susceptible to MSDs than their male colleagues (Hayes et al., 2009; Puriene et al., 2007), it will become increasingly important to explore different ways to lower the work load and improve postures associated with dental activities.

sEMG has been widely used both as a research and a clinical tool. It's non-invasive and non-painful character makes the method acceptable to most subjects. The use of surface electrodes gives a more general idea about the activity of a muscle opposed to the activity of individual muscle fibres and motor units with the use of fine wire electrodes. Consequently sEMG was the most appropriate choice in the present study. Nevertheless it needs to be taken into account that sweating of the participant might result in loosening of electrodes and/or distorted measurements. Apart from this, non-normalized sEMG data were used. As such these data are specific to an individual and posture at a certain moment in time and can change over time. Therefore the results should be interpreted with caution.

The performance of the BodyGuard™ system within this study supports its use as a relatively simple and cost-effective solution to objective postural analysis in relation to seated tasks. The calibration procedure in the present study was different from the calibration procedure described in former studies (O'Sullivan et al., 2011, O'Sullivan et al., 2012, O'Sullivan et al., 2012b). However, the focus in this study was on the extent someone works in a neutral position and not on extreme positions. When comparing BodyGuard™ and videofluoroscopy a greater error was found in the mid-range, which, according to the authors, was to be expected as the device was calibrated at end-range flexion and extension (O'Sullivan et al., 2012b). As the present study was meant to evaluate postures around neutral, the accuracy of the results around the neutral position were most important. The calibration procedure was therefore adapted as described.

The BodyGuard™ monitors spinal posture in the sagittal plane. It could be assumed that certain dentists in specific situations combine movement in the sagittal plane with movements in other planes. These movements were not monitored in the present study. Nevertheless, when comparing the posture monitor to a laboratory-based motion analysis system, non-sagittal movements or trunk rotation did not appear to be a very large source of error (O'Sullivan et al., 2012). A difference of only 0.25° for sitting with trunk rotation and 3.1° for sitting combined with side-flexion between the two systems was found. As it was not evaluated, a stool-specific variation in the amount of rotation or side-flexion cannot be ruled out, but is not to be expected. Taking into account the foregoing, it is

improbable that in the given circumstances the results would be influenced to a great extent by the movements in other than the sagittal plane.

To the authors' knowledge, no previous studies have examined the lumbo-pelvic posture in dentists during work. The fact that flexion on a saddle stool (-6°) was less than on the standard stool (4°) confirms the results of other studies (Gale et al., 1989; Koskelo et al., 2007). Both studies found that saddle seats are associated with increased lumbar lordosis. However none of these studies discusses the amount of lordosis compared to a neutral position. A more recent study (Grooten et al., 2013) found that the pelvis was tilted anteriorly during sitting on a stable saddle chair, although less than during standing, whereas the pelvis was rotated in a posterior direction while sitting on an office chair. From the trunk-to-thigh angle view the A-dec standard dental stool is most comparable with the office chair. In the present study, during calibration the zero point for the BodyGuard™ was set at the neutral lumbar position. The results show that the position on the Ghopec stool (1°) was most close to this neutral lumbar position, whereas the position on the standard stool was somewhat flexed. Contrary, on the saddle stool, the posture became somewhat hyperlordotic. This confirms what has been raised by some opponents of the saddle stool: because of increased spreading of the upper legs on a saddle stool, the pelvis tilts forward which leads to lumbar hyperlordosis. The absence of a lumbar support under the present circumstances indeed did not lead to increased flexion, which is a criticism often aimed at chairs without a backrest. On the other hand the range between minimum and maximum flexion for the saddle stool was larger than for both other stools, which at least partly will have been influenced by the absence of a backrest. Although some flexion on the standard stool was present, it was not excessive. As, in another study, yet during a typing task, extreme flexion was found on a standard backless office chair (O'Sullivan et al., 2012b), the limited flexion in the present study probably was due to the presence of a lumbar support and the attention given to adjust it correctly in both vertical and horizontal direction. Because of the great height and large contact area of the lumbar support, its adjustment was experienced as more difficult than for the Ghopec stool. The increased trunk-to-thigh angle together with the active pelvic support of the Ghopec stool seems to lead to the sitting posture most close to neutral.

Muscle activity of IO on the saddle stool was higher than on the Ghopec than on the standard stool and as such was concurrent with lumbar extension; the more lumbar extension, the higher IO activity was. Whilst higher activity may lead to fatigue in those muscles, it would be less likely to be a major issue in lower back pain where concern is much more focused on flexed than on extended postures (McGill, 2007). Contrary the activity of ICLT was lower on the saddle and Ghopec stool than on the standard stool. As most of the compressive force acting on the lumbar spine arises from tension in the back muscles, increased ICLT activity will lead to increased spinal loading which has been associated with lower back pain (Adams et al., 2007). In a former study on dentists (Hardage et al., 1983) the absence of a back rest lead to higher sEMG-levels in lower and upper back muscles. No differences were found between different stool heights or knee angles. These results are not confirmed by the present results. In the present study, not all back muscles, but at least ICLT showed less activity with 125° hip and knee angles than with 90° angles and no upper back muscles were evaluated. The set-up of both studies was not directly comparable however. Whereas in the present study 3 different types of stools were examined, in the former study the same stool at a different height was used on each occasion. Apart from this, electrodes were not in the same position and the present study did not compare the same stools with and without lumbar support. However the comparison between Ghopec and the saddle stool, both 125° hip and knee angle, the first with and

the latter without lumbar support, showed no difference in back muscle activity in contrast to higher abdominal activity if a back rest was absent (saddle stool). Nevertheless the present results confirm the results of two other studies, which found lower back muscle activity (MF or ICLT) when sitting in a 125° trunk-to-thigh angle compared to a 90° angle, although this was during an office task (O'Sullivan et al., 2012a; O'Sullivan et al., 2012b). Grooten et al. (2013) also found an association between posterior tilt of the pelvis on a conventional (office) chair and increased back muscle activity. Neither of these studies found significant differences in abdominal muscle activity though. Again, possibly the specifics of dental work, during which dentists not all the time rest against the lumbar support, contribute to the differences in results. In the context of the activities undertaken within this study, the standard stool has the least preferable combination of posture and muscle activity. It could be predicted that this type of seating will result in greater risk of lower back symptom reporting amongst dentists.

4.1 Limitations and recommendations for future research

Caneiro et al. (2010) described the influence of different sitting postures on head/neck posture and muscle activity and found that slump sitting with posterior rotation of the pelvis was associated with greater head/neck flexion and anterior translation of the head compared to 2 sitting postures with anterior rotation of the pelvis. They also found increased muscle activity of cervical erector spinae. Such findings, allied to the differences found at the lumbar level in the present study, dictate that upper back and neck muscle activity and head/neck position should be evaluated in further studies. The particular postural constraints facing dentists make this of particular importance for this occupational group.

The present study evaluated 3 different conditions each during 15.5 minutes. This is a rather short period compared to daily work in dental practice. One might expect that over a complete working day, muscle fatigue, which in this kind of experimental setting is probably not a major issue, will become more significant. Generally, muscle fatigue might result in a more slump posture with the participants. If subjects are well positioned on their stool and the back rest is well adjusted, the back rest will counteract this effect and subjects will be forced in a neutral lumbar posture. Nevertheless saddle stools most often do not possess a back rest, and it is not clear what will happen to the hyperlordotic posture in the presence of fatigue and whether this posture could evolve to a slump posture on this kind of stool. Former studies, evaluating posture during an office task, also evaluated only for 5 or 10 minutes (Grooten et al., 2013; O'Sullivan et al., 2012b). As such, more information is needed on what happens during a complete working day. Whilst it would not be convenient to perform sEMG in routine dental practice, the BodyGuard™ is conceived in such a way that longer evaluations outside the lab are perfectly possible and therefore field trials using this technology are recommended. The standard deviations show that there is a lot of variation between subjects for each type of stool, which means that general recommendations based on these results might not apply to every dentist. The best advice would probably be based on individual evaluation with the BodyGuard™ system. Whether or not the variation between subjects is also caused by the specifics of dental work is unclear. The task to be performed was indeed standardized, but it may be possible that, although the starting position was equal, subsequently there may have been a difference in tendency towards forward-bending between participants.

5 Conclusion

The use of the Ghopec stool, developed for health care workers, compared to a standard stool, facilitates a less flexed lumbar position while performing a simulated dental screening task at a phantom head. In comparison, the use of a saddle stool results in a somewhat hyperlordotic posture. Sitting with a larger trunk-to-thigh angle results in less activation of the lower paraspinal muscles, especially ICLT, and more activation of abdominal muscles, especially IO. However, the presence of a backrest decreases the activation of the abdominal muscles (IO). Based on these findings, to maintain the recommended neutral posture, the Ghopec is considered the most suitable of the 3 stools investigated.

Future studies should be directed towards the upper back and neck region. To ensure ecological validity, spinal postures should be evaluated over longer time periods in field trials.

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