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Variability of Musculoskeletal Strain on Dentists: An Electromyographic and Goniometric Study

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Introduction. *Dentists and hygienists are strongly affected by musculoskeletal disorders (MSDs). As workstation concepts are supported by subjective arguments only, the aim of this study was to use objective measurements to compare the variability of strain in various concepts: a dental chair equipped with a cart or an over-the-patient delivery system without an assistant, and Dr Daryl Beach's concept with an assistant.* ***Methods.*** *Goniometric and electromyographic recordings were made on 8 subjects, during a scaling operation. The electrical activity of their trapezius and lumbar muscles was compared, as were their cervical and lumbar ranges of motion.* ***Results.*** *The results showed that there was a wide variability depending on the workstation. However, the Beach concept tended to reduce physical strain on most parameters: duration of left lumbar muscle activity (2% compared to 15% of time spent in >10% maximal voluntary contraction, MVC), time spent in cervical side bending (4% compared to 30%), cervical flexion of >20° (9% compared to 40%), and left trapezius activity (9% of time spent >10% MVC compared to 28%).* ***Conclusion.*** *Practitioners and students should adjust their workstations to reduce the prevalence of MSDs.*

dental workstation electromyography goniometry musculoskeletal disorders

1. INTRODUCTION

Musculoskeletal disorders (MSDs) have become a significant issue for dentists and hygienists [1, 2, 3, 4, 5, 6, 7]. Finnsen, Christensen, and Bakke in 1998 showed a prevalence of MSDs of 65% for the neck and shoulders, and 59% for the lower back [8]. This presence of significant MSDs associated with high muscle and joint constraints, raises the question of the adaptation of the workstation.

Fauchard promoted the dental chair in the 18th century [9], when most dentists were still working standing. However, he thought that positioning the patient horizontally on the back was more convenient for the dentist. In the 20th century, dental work became increasingly elaborate and new dental workstations appeared.

Several different dental work concepts still exist nowadays: a dental chair equipped either with a cart (Bonsack, 1935, as cited in Société française d'histoire de l'art dentaire [10]) or an over-the-patient delivery system [11], and a working table proposed by Daryl Beach [12]. No strain comparisons have been made, but Smith, Sommerich, Mirka, et al. revealed that alternative methods for viewing teeth significantly reduced muscle activity, neck flexion, and discomfort, compared to the direct view [13].

Most practitioners use a dental chair and position their patient with a backrest half tilted. They do not usually follow any specific recommendation

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and position themselves according to their own choice, to see their task. Most dental work is done in direct view, and many dentists do not have an assistant to help them.

In the dental chair concept, the orientation of the oral cavity is opposite to the dentist's eyes. This causes high levels of cervical and lumbar flexion to meet the requirement of the eye–task distance.

The cart delivery system has a small dental unit on wheels, added on the side of the dental chair (Figure 1a). The aim is to have the instruments closer to the dentist's operating hand. A right-handed dentist is most of the time seated at 11 o'clock from the patient's head.

The over-the-patient delivery system has a tray suspended over the patient's chest, to bring the instruments closer to the patient's mouth (Figure 1b). The dentist is mainly seated at 9 o'clock. The problem is that this causes important scapulohumeral flexion to reach the instruments when the operator is at 12 o'clock, and important scapulohumeral lateral rotation when the operator is at 9 o'clock.

In the Beach concept, the patient is completely lying on a working table, the work is done mostly in indirect view, and in direct view when it is possible (Figure 1c). The dentist is mainly seated at 12 o'clock, and has an assistant for water suction and dental mirror cleaning. The instruments are as close as possible to the head of the patient and to the dentist's operating hand.

The aim of this study was to determine, with objective measurements, if the practitioner's musculoskeletal strain varied depending on the workstation. This required analyzing possible impact of various workstation concepts (dental chair or working table, cart or over-the-patient delivery system, help of an assistant or not), on the practitioner's muscles and joints: maximal muscle activity; mean and maximal range of motion (cervical flexion, lumbar flexion, side bending); and holding times beyond a contraction threshold.

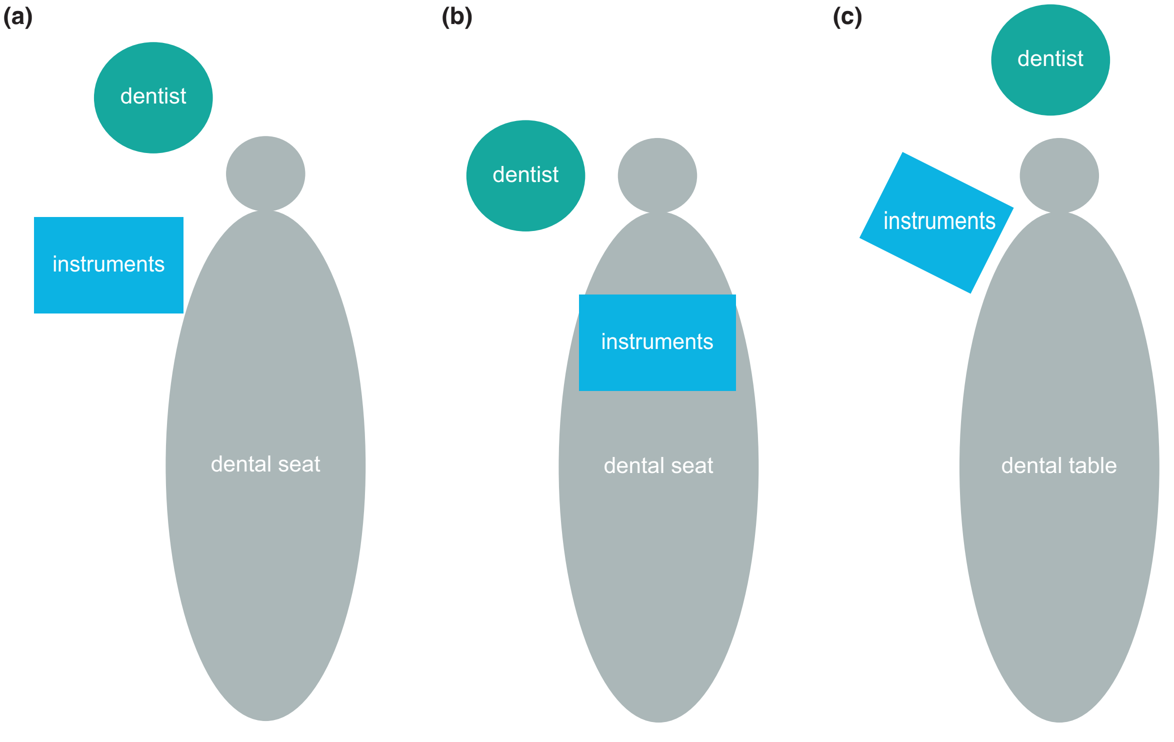


Figure 1. Situation of the dentist and of the instruments around the mouth of the patient, in 3 different concepts: (a) dental chair + cart, (b) dental chair + over-the-patient delivery system, (c) dental table fitting the Beach concept.

2. MATERIALS AND METHODS

2.1. Subject Selection

Six subjects were selected (5 males and 1 female). The 5 males were all experienced doctors in dental surgery, and the female was a dental surgery student. She had 2 years' experience in dental work at the faculty of dentistry. The subjects were 22–65 years old. Each one was recorded working on their usual dental unit, not to have a habituation time that would confound the results. Two other sessions were realized with the student. She was the only one who also practiced the two other concepts. Thus, there was a total of eight recording sessions. This student was compared on three concepts, the results are considered as a case report.

session 1: dental chair + cart without assistant;
session 2: student with dental chair + cart without assistant;
session 3: Beach concept + assistant;
session 4: Beach concept + assistant;
session 5: student with Beach concept + assistant;
session 6: student with dental chair + over-the-patient delivery system without assistant;
session 7: dental chair + over-the-patient delivery system without assistant;
session 8: dental chair + over-the-patient delivery system without assistant.

Having an assistant in the Beach concept was chosen because it is part of the recommendations of this concept. Having no assistant with the dental chair was chosen because it corresponds to a large proportion of the practitioners in some countries. An inclusion criterion was that the practitioner should be right-handed. Algesic subjects were excluded because of the possibility that their movements would be restricted.

All subjects accepted to participate in the study, and to allow the results to be used in scientific analyses. All the recording materials were noninvasive.

2.2. Task Studied

Ultrasound root scaling followed by polishing with a brush, polishing paste, and hand piece was chosen. This involved working on the entire surface of each face of each tooth. Scaling was performed on patients who had not had such treatment for at least 1 year.

Two recording sessions were conducted using a dental chair + cart without an assistant (Figure 2a), three sessions using a dental chair + over-the-patient delivery system without an assistant (Figure 2b), and three sessions with a dental table fitting the Beach concept + assistant (Figure 2c). The student practitioner performed the scaling using all the concepts (sessions 2, 5, 6).

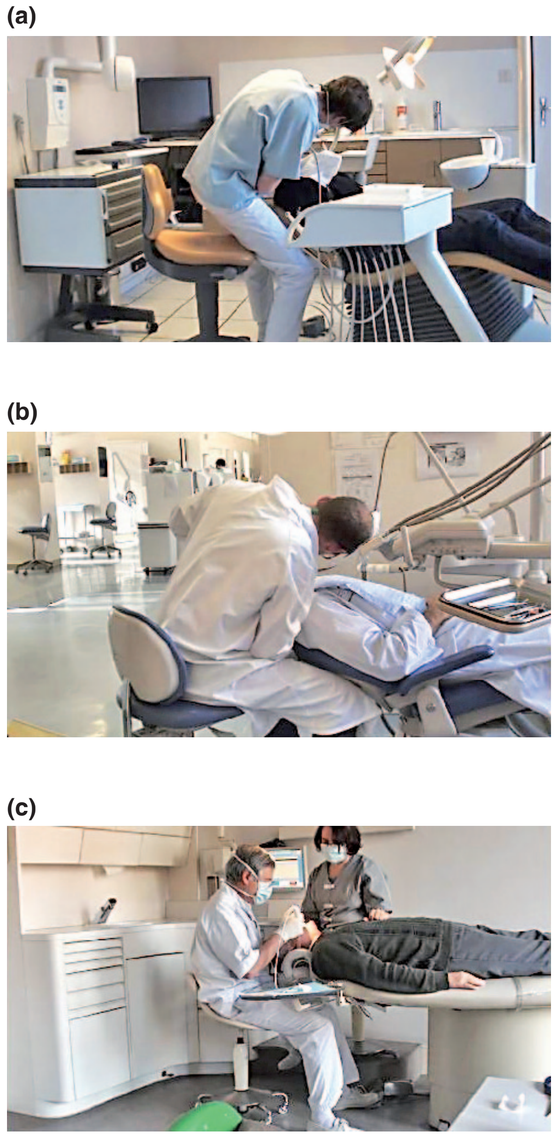


Figure 2. Working positions during the recordings: (a) dental chair + cart, (b) dental chair + over-the-patient delivery system, (c) dental table fitting the Beach concept.

The dentist's stool was traditional, only its height changed, according to the height of the dentist. The hip flexion was slightly under 90°.

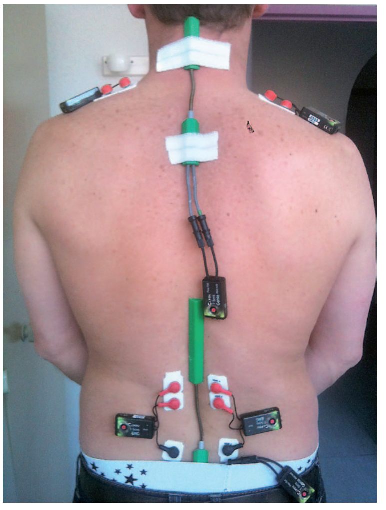
2.3. Electromyography (EMG)

Figure 3a presents the position of the electrodes and sensors. Surface bipolar electrodes were used to record the electrical activity of the muscles that are reported in the literature as major areas of pain among dentists. These muscles are upper trapezius and lumbar erector spinae muscles. EMG signals were obtained with Thought Technology® (Canada) self-adhesive electrodes, type T3404, diameter 1 cm, with a center-to-center spacing of 3 cm. The electrodes of the upper trapezius were positioned equidistantly between the acromion and the spinous process of C7. The reference electrode was positioned on an area that had no muscle fibers (the upper side of the clavicle) to avoid capturing any electrical activity. The electrodes of the lumbar erector spinae were positioned on either side of the spinous processes line, facing L3, at the top of the muscle body. The sensors used (T-sens sEMG[1]) were wireless, (weight 20 g, dimensions 52 × 25 × 14 mm). They were attached to the electrodes with snaps and fixed to the skin with an adhesive. They transmitted the measurements to a Datalogger module.

The electrical activity was measured in microvolts, sampling was at 2048 Hz, with 128 Hz RMS calculation. The data were transferred to Captiv L-7000 software[1] developed in collaboration with the French National Institute for Research and Safety (INRS), and running on Windows™. This software makes it possible to synchronize video and electrical recordings, and to calculate mean and maximal values, and time spent over a threshold.

Before scaling, the maximal voluntary contraction (MVC) of each muscle was measured. Each muscle was positioned in intermediate excursion and a maximal static contraction against the operator's manual resistance was requested. For the upper trapezius, the subject stood, arm along the body, and was instructed to only raise the shoulder, keeping the arm straight, with the hand closed, while the operator held the subject's wrist (Figure 3b). For the lumbar erector spinae muscles, the subject lay face down and lifted the legs and head against the operator's manual resistance (Figure 3c).

(a)



(b)

(c)

Figure 3. Preparation of goniometers and electromyographic recordings: (a) positions of sensors and electrodes, (b) recording MVC of left upper trapezius, (c) recording MVC of lumbar spinal muscles. *Notes.* MVC = maximal voluntary contraction.

[1] http://www.teaergo.com

Maximal contraction was requested, motivated orally, and repeated three times. The best score was kept. The absolute values of the measurements in microvolts were normalized against the MVC and expressed as percentages of MVC.

2.4. Electrogoniometry

Angular measuring sensors from Biometrics™ (UK) were connected to a wireless transmitter amplifier (T-sens gonio [2]). They had two data channels (flexion/extension and right/left side bending) and were connected via the Datalogger module to the Captiv L-7000 software. Measurements were recorded in degrees, 0° being calibrated on a flat table. The measurement range was ±180°, the frequency was 32 Hz per channel, and the accuracy was 2°.

These sensors were positioned so that the shaft between the sensors was located between the spinous processes of C6 and T2 for the cervical region, and between L2 and the sacrum for the lumbar region (Figure 3a). As this distance varied from one subject to another, the parts of the T-sens gonio were positioned using manual anatomical identification by palpation.

2.5. Video

The whole scaling procedure was video recorded. The subject was filmed full length (head to foot), in profile (Figure 2). The video file was synchronized with the EMG and goniometer, to appear in the Captiv L-7000 software. This synchronization made it possible to determine the beginning and the end of the procedure. It also made it possible to eliminate artifacts that could correspond to accidental situations, independent from the scaling procedure.

2.6. Session Recording

At the beginning of each session, the subject was filmed standing in an anatomical reference position to calibrate the 0° of the goniometer. Practitioners were asked to act as they normally did from the beginning of scaling. For her session on the dental table fitting the Beach concept, the student was given some basic recommendations to help her to respect Beach's principles.

2.7. Analyzed Parameters

The electrical activity of the left and right upper trapezius, and the left and right lumbar erector spinae muscles was recorded in microvolts. Lumbar and cervical ranges of motions were recorded in degrees, in the sagittal and coronal planes (Figure 4).

The durations of scaling varied according to the working habits of the dentist and the degree of calcification. The measurements were converted through Microsoft Excel™ to a percentage of working time beyond a limit. There were two reasons for this: we obtained comparable values, and we could test what was most harmful for the muscle. Static contraction creates cellular hypoxia, even at low intensity. This is the Cinderella hypothesis discussed by Kadefors, Forsman, Zoéga, et al. [14], and characteristic of dental work; low intensity but maintained for a long time.

Captiv L-2100 provided the duration of electrical activity exceeding a threshold during the task, as well as the mean range of motion. The thresholds for cervical comfort ranges of motion were determined with rapid upper limb assessment (RULA) [15], based on the studies of the cervical spine by Chaffin [16] and Kilbom, Persson, and Jonsson [17, 18]; and of the trunk by Drury [19]; Grandjean [20]; and Grandjean, Hünting, and Pidermann [21]. In this method, a score is obtained based for the measured range of motion: 1 for 0°–10°, 2 for 10°–20°, 3 for >20°, and 4 for cervical extension (Figure 5). These thresholds were used as warning levels.

For the lumbar region, mean ranges of motion quoted by Kapandji [22] are 40° of lumbar flexion and 30° of extension. The threshold for convenience range of motion was considered as an intermediate excursion, i.e., between 6° of extension and 17° of flexion.

[2] http://www.teaergo.com

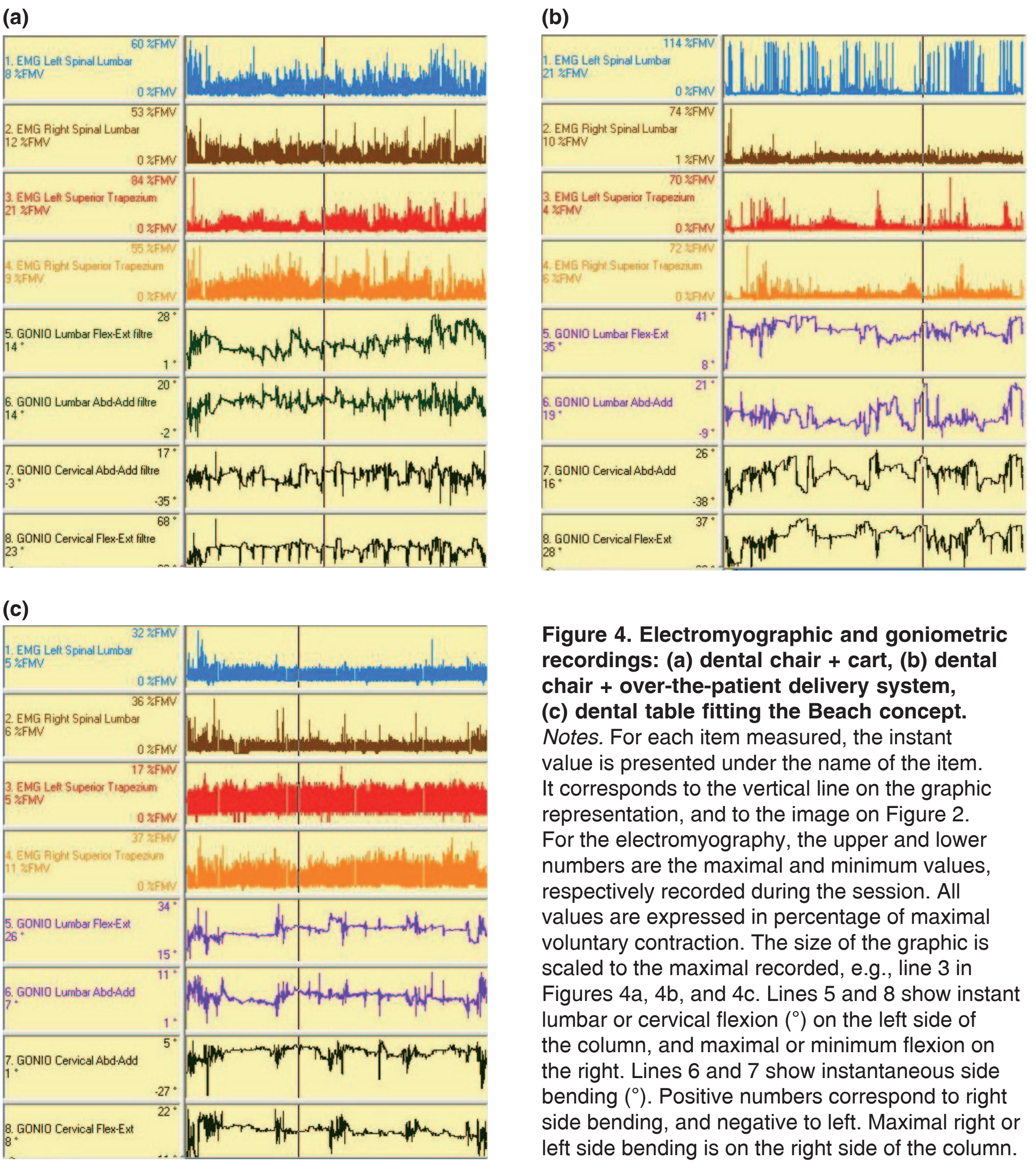


Figure 4. Electromyographic and goniometric recordings: (a) dental chair + cart, (b) dental chair + over-the-patient delivery system, (c) dental table fitting the Beach concept. *Notes.* For each item measured, the instant value is presented under the name of the item. It corresponds to the vertical line on the graphic representation, and to the image on Figure 2. For the electromyography, the upper and lower numbers are the maximal and minimum values, respectively recorded during the session. All values are expressed in percentage of maximal voluntary contraction. The size of the graphic is scaled to the maximal recorded, e.g., line 3 in Figures 4a, 4b, and 4c. Lines 5 and 8 show instant lumbar or cervical flexion (°) on the left side of the column, and maximal or minimum flexion on the right. Lines 6 and 7 show instantaneous side bending (°). Positive numbers correspond to right side bending, and negative to left. Maximal right or left side bending is on the right side of the column.

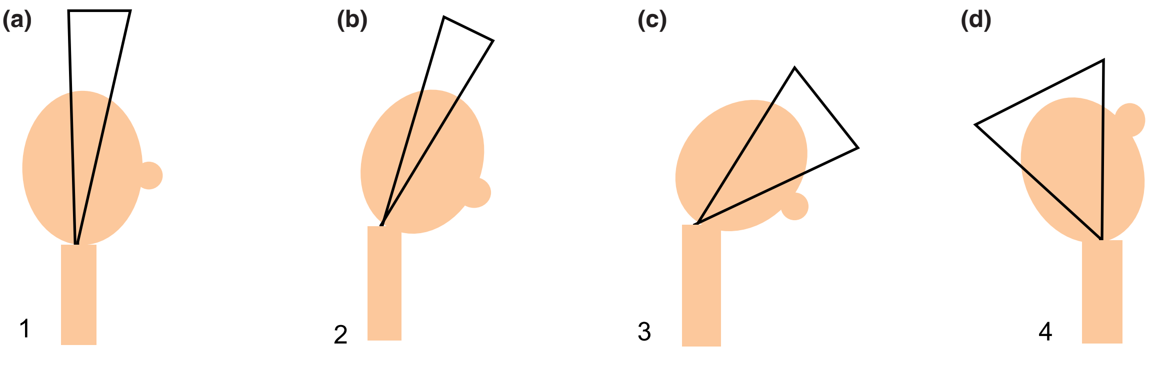


Figure 5. Rapid upper limb assessment (RULA) [15] scoring of cervical range of motion. *Notes.* (a) 0°–10°, (b) 10°–20°, (c) >20°, (d) in extension. Add 1 if the neck is twisted, add 1 if the neck is in side bending.

For the evaluation of time spent in tilted positions, the limit was set at 10° of side bending, left or right, for the cervical and lumbar spine. These 10° of right and left limits correspond also to the intermediate excursion quoted by Kapandji [22].

The EMG limit was set to 10% MVC for all subjects, to make the values comparable. Percentages of time spent in >10% MVC were compared; 10% MVC is the limit where blood circulation in the muscle is impeded [23].

2.8. Statistical Analysis

For each item measured, calculation of the mean and standard deviation allowed to determine the importance of the variability of musculoskeletal strain between practitioners (Tables 1–2). Table 3 compares mean values for two situations: the Beach concept + assistant versus both dental chairs without assistant. A ratio was calculated for each pair of values, to bring out the importance of the difference between the compared situations.

Table 4 presents the values of the subject who used all concepts. Twenty-three items were compared, but only 21 could be considered as representing high musculoskeletal strain. Actually, time spent in 0°–10° and 10°–20° of cervical flexion are rather low strain criteria.

TABLE 1. Lumbar Electromyographic (EMG) and Goniometric Measurements, for Each Practitioner

	Recording Session								
Item Measured	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	***M* (*SD*)**
Maximal left lumbar EMG (%MVC)	58	79	24	27	30	39	87	90	54.25 (27.92)
Maximal right lumbar EMG (%MVC)	53	85	37	36	31	38	80	41	50.13 (20.99)
Left lumbar EMG: time spent in >10% MVC (%SS)	21	8	0	2	0	9	21	17	9.75 (8.94)
Right lumbar EMG: time spent in >10% MVC (%SS)	17	4	3	1	0	4	0	7	4.50 (5.58)
Mean lumbar flexion (°)	13	28	29	25	27	21	13	32	23.50 (7.21)
Maximal lumbar flexion (°)	28	45	32	34	40	40	35	40	36.75 (5.47)
Time spent in >17° of lumbar flexion (%SS)	18	71	100	100	100	83	20	100	74.00 (35.55)
Time spent in lumbar side bending of >10° (%SS)									
left	0	1	0	0	2	11	0	0	1.75 (3.81)
right	82	4	0	0	0	0	63	9	19.75 (33.10)
Total time spent in lumbar side bending of >10° (%SS)	82	5	0	0	2	11	63	9	21.50 (32.13)

Notes. SD shows the dispersion between the values; "time spent" corresponds to the percentage of the scaling session (%SS); MVC = maximal voluntary contraction.

TABLE 2. Cervical Electromyographic (EMG) and Goniometric Measurements, for Each Practitioner

	Practitioner								
Item Measured	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	***M* (*SD*)**
Maximal left upper trapezius EMG (%MVC)	63	90	67	17	35	66	80	70	26.40 (23.78)
Maximal right upper trapezius EMG (%MVC)	52	39	41	37	35	49	87	72	51.50 (18.65)
Left upper trapezius EMG: time spent in >10% MVC (%SS)	40	15	27	1	1	42	32	8	20.75 (16.74)
Right upper trapezius EMG: time spent in >10% MVC (%SS)	34	15	14	32	3	4	19	8	16.13 (11.79)
Mean cervical flexion (°)	20	20	16	9	15	12	18	16	15.75 (3.81)
Maximal cervical flexion (°)	68	40	24	22	32	39	44	37	38.25 (14.29)
Time spent in cervical side bending of >10° (%SS)									
left	29	17	4	0	0	3	27	15	11.88 (11.84)
right	1	26	7	0	0	9	3	20	8.25 (9.79)
Total time spent in cervical side bending of >10° (%SS)	30	44	11	0	0	12	31	35	20.38 (16.76)

Notes. Standard deviation shows the dispersion between the values; "time spent" corresponds to the percentage of the scaling session (%SS); MVC = maximal voluntary contraction.

TABLE 3. Comparing Mean Results Between Beach Concept and Dental Chair

Item Measured	A	B	Ratio
Items where Beach concept + assistant caused less strain			
time spent in right lumbar side bending of >10° (%SS)	0	32	—
total time spent in lumbar side bending of >10° (%SS)	1	34	34.0
time spent in left cervical side bending of >10° (%SS)	2	18	9.0
total time spent in cervical side bending of >10° (%SS)	4	30	7.5
left lumbar EMG: time spent in >10% MVC (%SS)	2	15	7.5
right lumbar EMG: time spent in >10% MVC (%SS)	1	7	7.0
time spent in cervical extension (%SS)	1	6	6.0
time spent in right cervical side bending of >10° (%SS)	2	12	6.0
time spent in >20° cervical flexion (%SS)	9	40	4.4
left upper trapezius EMG: time spent in >10% MVC (%SS)	9	28	3.1
maximal left lumbar EMG (%MVC)	27	71	2.6
time spent in left lumbar side bending of >10° (%SS)	1	2	2.0
maximal left upper trapezius EMG (%MVC)	40	74	1.9
maximal cervical flexion (°)	26	46	1.8
maximal right lumbar EMG (%MVC)	35	60	1.7
maximal right upper trapezius EMG (%MVC)	38	60	1.6
mean cervical flexion (°)	13	17	1.3
Items where means are similar			
maximal lumbar flexion (°)	35	38	1.0
right upper trapezius EMG: time spent in >10% MVC (%SS)	16	17	1.0
Items where strain seems lower with dental chair without assistant			
mean lumbar flexion (°)	27	21	0.8
time spent in lumbar flexion of >17° (%SS)	100	64	0.6
Low strain items			
time spent in 0°–10° of cervical flexion (%SS)	31	16	0.5
time spent in 10°–20° of cervical flexion (%SS)	60	38	0.6

Notes. Significant differences exist between Beach concept + assistant, and dental chair without assistant; ratio = dental chair without assistant/Beach concept + assistant; “time spent” corresponds to the percentage of the scaling session (%SS); A = Beach concept + assistant, B = dental chair without assistant; MVC = maximal voluntary contraction.

3. RESULTS

3.1. Comparing 8 Sessions

3.1.1. Lumbar region

Table 1 shows that lumbar strain had a high variability according to the practitioner. Differences were substantial for time spent in right side bending (0%–80% of the time, *SD* 33.1), for time spent in >17° of flexion (18%–100%, *SD* 35.55), and erector spinae electrical activity (maximal left EMG of 24%–90% MVC, *SD* 27.92, and 0%–21% of time >10% MVC, *SD* 9). Differences were lower for time spent in left side bending (*SD* 3.81), and right erector spinae duration of contraction (*SD* 5.58).

3.1.2. Cervical region

Table 2 shows that cervico-scapular strain also had a high variability according to the practitioner. Differences were substantial for upper trapezius electrical activity, especially on the left side (maximal EMG of 17%–90% MVC, *SD* 23.78, and time spent in >10% MVC 1%–42% of time, *SD* 16.74). Moreover, maximal cervical flexion was distributed between 22° and 68°, *SD* 14.29, and time spent in side bending of 0%–44% of the time, *SD* 16.76. The differences were lower for mean flexion (*SD* 3.81).

Distribution of time spent in different cervical ranges of motion showed differences according to the practitioner (Figure 6). Numbers 3, 4, and 5,

TABLE 4. Results Showing Musculoskeletal Strain on the 23 Items, for the Same Subject Who Performed on All Concepts

Item Measured	A	B	C
Items having lower values with Beach concept + assistant			
left lumbar EMG: time spent in >10% MVC (%SS)	0	2	6
right lumbar EMG: time spent in >10% MVC (%SS)	0	4	4
time spent in right lumbar side bending of >10° (%SS)	0	4	0
time spent in left cervical side bending of >10° (%SS)	0	18	3
time spent in right cervical side bending of >10° (%SS)	0	26	9
total time spent in cervical side bending of >10° (%SS)	0	44	12
left upper trapezius EMG: time spent in >10% MVC (%SS)	1	15	42
right upper trapezius EMG: time spent in >10% MVC (%SS)	3	15	5
time spent in cervical extension (%SS)	3	4	12
total time spent in lumbar side bending of >10° (%SS)	3	5	11
time spent in >20° of cervical flexion (%SS)	12	55	19
maximal cervical flexion (°)	32	40	39
maximal left lumbar EMG (%MVC)	30	79	39
maximal right lumbar EMG (%MVC)	31	85	38
maximal left upper trapezius EMG (%MVC)	35	90	66
maximal right upper trapezius EMG (%MVC)	35	39	49
Items having intermediate values with Beach concept + assistant			
time spent in left lumbar side bending of >10° (%SS)	3	1	11
mean cervical flexion (°)	15	20	12
mean lumbar flexion (°)	27	28	21
maximal lumbar flexion (°)	40	45	40
Items having higher values with Beach concept + assistant			
Time spent in lumbar flexion of >17° (%SS)	100	71	83
Low strain items			
Time spent in 0°–10° of cervical flexion (%SS)	12	17	32
Time spent in 10°–20° of cervical flexion (%SS)	74	25	36

Notes. "Time spent" corresponds to the percentage of the scaling session (%SS); A = Beach concept + assistant, B = dental chair + cart without assistant, C = dental chair + over-the-patient delivery system without assistant; MVC = maximal voluntary contraction.

who used the Beach concept + assistant, spent less time in >20° of cervical flexion and less time in extension than the others.

3.2. Comparing 2 Situations: Dental Chairs Without Assistant and Beach Concept + Assistant

Mean ranges of motion and measured EMG activity for dental chairs without assistant and the Beach concept + assistant, revealed that practitioners working according to the Beach concept + assistant had lower strain on 17 out of 21 items (Table 3).

3.2.1. Lumbar region

Mean values obtained with the Beach concept + assistant were lower than with a dental chair without assistant, with a high ratio up to 34. The differences were higher for lumbar side bending (1% of the scaling session compared to 34%) and left lumbar EMG (2% of time spent in >10%MVC compared to 15%).

3.2.2. Cervical region

Mean values obtained with the Beach concept + assistant were also lower than with a dental chair without assistant, with a high ratio up to 9. The

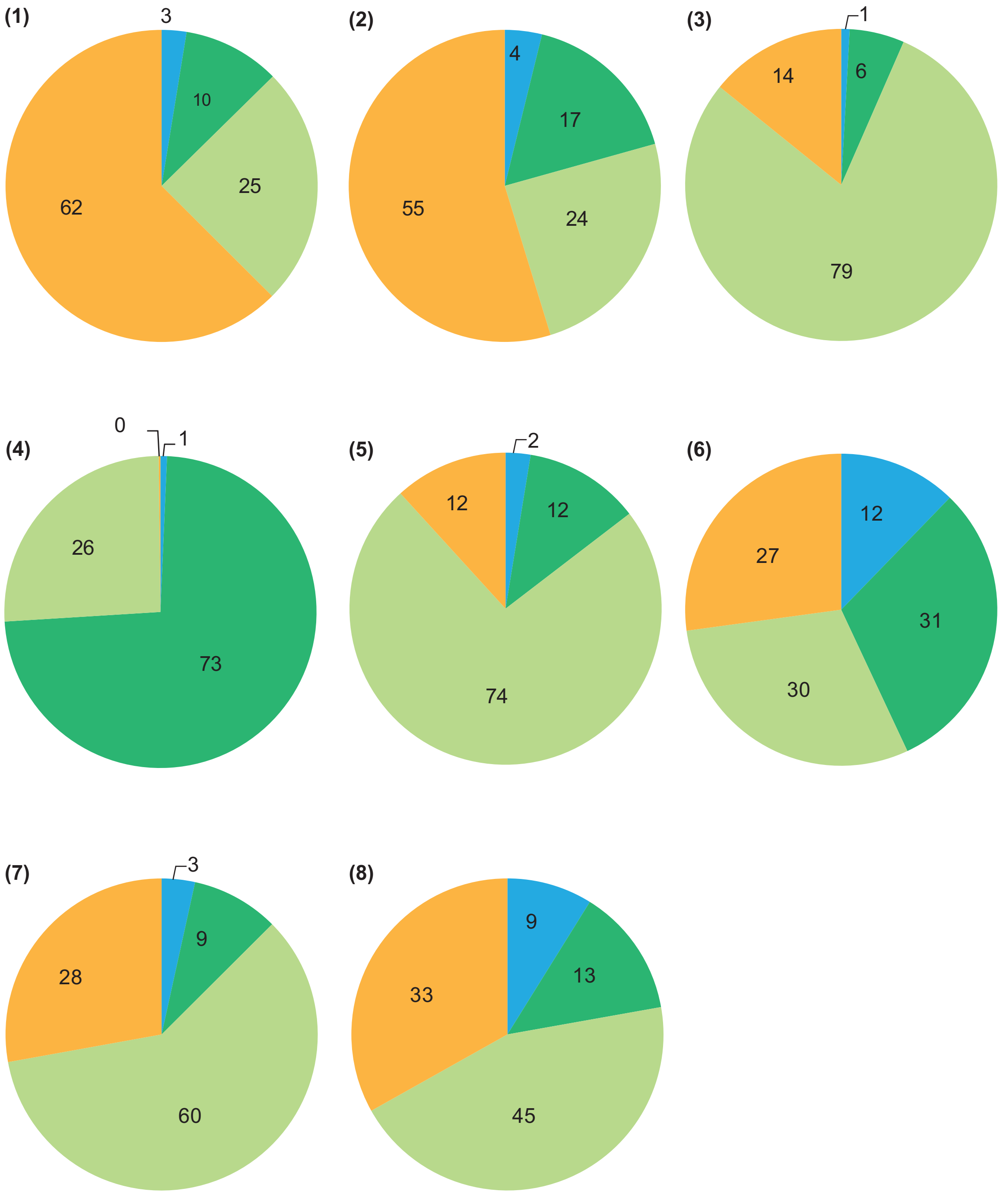


Figure 6. Distribution of time spent in various cervical ranges of motion, for the 8 recording sessions (in percentage of the scaling session). *Notes.* ■ = time spent in cervical extension, ■ = time spent in 0°–10° of cervical extension, ■ = time spent in 10°–20° of cervical extension, ■ = time spent in >20° of cervical extension.

major differences were for cervical side bending (4% compared to 30%), time spent in >20° of cervical flexion (9% compared to 40%), and left upper trapezius (9% of time spent in >10%MVC compared to 28%).

3.3. One Subject Used 3 Concepts

This subject had lower values with the Beach concept + assistant than the two other ones, for 16 items out of 21 (Table 4).

4. DISCUSSION

The aim of the study was to determine if there were differences between musculoskeletal strain, depending on the workstation concept. The high variability of the outcomes shows that dental workstations are not equal in terms of stress. Some reduced the strain; others increased it, but not homogeneously on different anatomical regions. Some situations can be analyzed.

In sessions 1 and 7, low lumbar flexion involved important cervical flexion. This compensation could have been used to meet the required eye–task distance. When the practitioner tried to keep his lumbar spine straight, he bent his head forward to see the task. In session 8, the practitioner had even high flexion in both the cervical and lumbar regions.

Concerning lumbar flexion, the higher values in sessions 3, 4, and 5 were probably related to the lower position of the practitioner's chair. Moreover, the electrical activity of lumbar muscles was very low. However, in sessions 2 and 8, the practitioners combined high lumbar flexion and high electrical activity. They were leaning forward, which is an MSD risk factor.

In some cases, there was compensation between lumbar and cervical side bending. In session 2, the subject had a low duration of lumbar side bending, and the duration of cervical side bending increased to compensate. In sessions 1 and 7, the practitioners spent more time in right lumbar side bending, and so left cervical side bending time increased. This is an uncomfortable position, which also involves considerable contraction of left lumbar muscles to hold the position. This association of flexion and side bending creates a rotation of the spine, which is a risk factor of MSDs, too.

However, some differences were low between the eight sessions. This was the case for time spent in left lumbar side bending, and the electrical activity of right lumbar muscles. This shows that practitioners have in common spending little time in left side bending.

In their study on the operator's chair, Verkindere, Lacombe, and Lodter considered prolonged muscular contraction a positive factor protecting the spine [24]. However, most articles consider low electrical activity to be less harmful [3, 4, 5, 6]. Muscle activity is essential to maintain the spine and to protect against MSDs during punctual physical activities such as carrying loads. However, dental activity requires prolonged postural support and one can wonder if slight muscle activity would not be preferable to sustained muscular contractions.

When mean values are compared by concept, some results tend to show that practitioners who work with the Beach concept + assistant have lower musculoskeletal strain. There were also differences in left lumbar muscles, cervical flexion, cervical side bending, and electrical activity of the left upper trapezius. There is, therefore, a trend towards lower strain, but further studies should confirm this.

The limitations of this study are (a) the small size of the sample, making the results not significant; (b) the fact that all subjects were not recorded on each working concept. Unfortunately in that case, the learning parameter and the adaptation time could increase strain in the practitioners who were not used to working according to some concepts (especially the indirect vision use).

Further studies should consider that, to isolate the elements that could modify strain, the dental workstation should be standardized, and one parameter at a time be modified:

- The hip flexion angle, modified by the height of the dental chair, to determine the consequence on lumbar flexion.
- The eye–task distance, by the oral cavity height.
- The backrest tilting angle, or even using a flat working table.
- Use of direct or indirect view.
- Presence or absence of an assistant. An assistant's help is expected to improve the results, but only on the practitioner's left upper limb. Presumably there are no consequences on ranges of motion and muscular activity on spine, but the hypothesis has to be verified.
- The choice of the type of instrument tray and its location.
- The position of the practitioner, relative to the patient, e.g., at 9 or 12 o'clock.

Finally it would be interesting to evaluate the efficiency of the treatment, and the patient's comfort, to make sure modifications of the dental workstations do not decrease the quality of the treatment. All these elements should be considered when designing comparative studies with a higher level of evidence. Their aim would be to determine which concept causes least strain, and so is likely to reduce the prevalence of MSDs. The difficulty in changing working habits is an obsactle to this reduction. It may seem important for most practitioners. Time pressure appears due to the lack of automatisms, and common tasks have to be relearned. Only the occurrence of MSDs initiates some efforts, and practitioners' motivation is proportional to their pain level. Learning working positions at an early stage in dental schools, at a time when habits have not been acquired yet, is probably a solution to consider.

5. CONCLUSION

These results allow validating the methodology. The use of EMG and electrogoniometry showed that a dentist's musculoskeletal strain is quantifiable, comparable, and especially very variable according to the workstation. The different working concepts are, therefore, not equal in terms of musculoskeletal stress. It should be possible to decrease MSDs by improving equipment and learning favorable ergonomic positioning for the patient and the practitioner.

Comprehension of human biomechanics applied to the dental workstation [25], such as the results of evidence based dentistry, should make it possible to modify practitioners' and equipment designers' habits. Therefore, dentists may objectively decrease their musculoskeletal strain, while improving the patient's comfort.

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