



**HAL**  
open science

## Exploring the utility of motion analysis in osteopathic clinical trials; a school-based pilot study on jaw and cervical range of motion

T. Bagory, P. Vaucher, H. Mhadhbi, M. Menard

► **To cite this version:**

T. Bagory, P. Vaucher, H. Mhadhbi, M. Menard. Exploring the utility of motion analysis in osteopathic clinical trials; a school-based pilot study on jaw and cervical range of motion. *International Journal of Osteopathic Medicine*, 2021, 41, pp.27-36. 10.1016/j.ijosm.2021.05.007 . hal-03368103

**HAL Id: hal-03368103**

**<https://hal.science/hal-03368103>**

Submitted on 15 Oct 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

**Title**

Exploring the Utility of Motion Analysis in Osteopathic Clinical Trials; a School-Based Pilot Study on Jaw and Cervical Range of Motion.

Bagory T.<sup>1</sup>, Vaucher P.<sup>2,3</sup>, Mhadhbi H.<sup>1</sup>, Ménard, M.<sup>1,3,4</sup>

<sup>1</sup>Institut d'Ostéopathie de Rennes – Bretagne (IO-RB), Campus Rennes Atalante Ker-Lann, 50 rue Blaise Pascal, 35170 Bruz (France).

<sup>2</sup>Unit of Research in Mobility & Musculoskeletal Care, School of Health Sciences Fribourg, University of Applied Sciences and Arts Western Switzerland (HES-SO), Fribourg (Switzerland).

<sup>3</sup>Clinical-Human Research Department, Nonprofit Foundation COME Collaboration, Via A. Vespucci 188, 65126, Pescara, Italy.

<sup>4</sup>Univ Rennes, M2S - EA 7470, F-35000 Rennes (France)

**Corresponding author:** Mathieu Ménard

Institut d'Ostéopathie de Rennes – Bretagne (IO-RB), Campus Rennes Atalante Ker-Lann  
50 Rue Blaise Pascal, 35170 Bruz, France.

Mail : [menard.m@io-rennes.fr](mailto:menard.m@io-rennes.fr)

**Title**

Exploring the Utility of Motion Analysis in Osteopathic Clinical Trials; a School-Based Pilot Study on Jaw and Cervical Range of Motion.

Journal Pre-proof

## 2 ABSTRACT

3 *Introduction:* This study explores the interest of using motion analysis to evaluate cervical  
4 and jaw ROM on students with or without bruxism when comparing Osteopathic  
5 manipulative treatment (OMT) to sham in school settings.

6 *Methods:* A feasibility study was run with 48 volunteer students from an osteopathic training  
7 institution. Random sequence for allocation was generated using a 1:1 ratio and block size of  
8 four to either OMT or sham treatment (control group). The chosen motion outcomes of  
9 interest were the lateral jaw range of motion, jaw opening, cervical rotation and side-bending.  
10 ROM was measured averaging over three repeated movements at baseline, immediately after  
11 the 1st treatment, one week before the 2nd treatment, and immediately after second treatment  
12 using video-based analysis with 15 body landmarks.

13 *Results:* Repeated measures of joint motion at baseline showed high levels of reliability (ICC  
14 ranging from 0.953 to 0.985). Motion analysis detected clinically important differences  
15 between OMT and sham one-week post-treatment for jaw lateral ROM (3.3°; p=0.018) and  
16 cervical rotation ROM (12.0°; p=0.003) on participants with bruxism but not on those  
17 without. Magnitude of differences were increased for all parameters following the second  
18 treatment (lateral jaw movement; 4.8°, p=0.005; jaw opening; 5.5°, p=0.002; cervical side-  
19 bending; 9.2°, p=0.023; cervical rotation; 18.2°, p<0.001).

20 *Conclusion:* Motion analysis is capable of detecting the effects of OMT on cervical and jaw  
21 ROM in students with bruxism but not without. Finally, the study showed the feasibility of  
22 introducing usual standards for clinical trials and sham treatment in school led studies with  
23 students.

24

25 **Keywords:** bruxism, osteopathic manipulative treatment, movement analysis, range of  
26 motion, cervical spine

## 27 INTRODUCTION

### 28 *Background*

29 Bruxism is a common behaviour that is associated with several other clinical musculoskeletal  
30 symptoms (neck pain, headache, tinnitus, sleep disorders, temporomandibular pain, etc.)[1–6].

31 Its prevalence is similar worldwide and concerns 20% of the population, decreases with age  
32 and appears to be very common among students [7–10].

33 Preliminary studies have highlighted interrelations between cervical spine and jaw  
34 musculoskeletal functions [11]. Many associations supported by anatomical, physiological,  
35 biomechanical and neurophysiological studies support the idea that the musculoskeletal  
36 system of the head, the cervical spine and/or the craniocervical- mandibular system are linked  
37 [11–15]. However, other causes that regulate motion, such as central neurological processes,  
38 could be at play. Therefore, alternative approaches that address other body regions or use  
39 different approaches (ex. mindfulness, stress management, lifestyle change, etc.) could also be  
40 beneficial.

41 Osteopaths make a substantial contribution to primary healthcare provision to a diverse  
42 population [16, 17]. This also includes the management of patients with bruxism and neck  
43 pain [17–20]. Osteopathy is a person-centred, primary health care discipline that often relies  
44 on touch to help to optimize, to restore, and to maintain functional balance and well-being  
45 [21, 22].

46 A large debate persists in the literature about osteopathic ability to evaluate motion and  
47 dysfunction; however, most studies agree that osteopathic tests lack fidelity and accuracy  
48 [23–26]. Specific and functional tests help osteopaths to analyse and evaluate the structural  
49 and functional integrity of the body in line with critical reasoning using osteopathic principles  
50 [25, 27]. Osteopathic motion tests remain very subjective and seem inappropriate to detect  
51 “somatic dysfunctions” as a simple dichotomous answer [24]. Pattern recognition could be the

52 way clinicians use motion tests thereby making it possible to detect subtler nuances in motion.  
53 Tests might be interpreted in a broader manner than we think and also use motion detection to  
54 detect abnormal muscular response during active self-induced polyarticular motions.  
55 Osteopathic motion tests could falsely target specific joint functions when in reality they  
56 provide information on a much more complex motion behaviour. Some behavioural pattern  
57 could reveal the intricate relationship of a whole chain of interlinked subcomponents that can  
58 only be correctly appreciated when considering motion in its entirety [28–30]. This approach  
59 for clinical interpretation is close to Johnston’s concept of “*bony segments as mobile units*  
60 *within a mobile system*” [31]. His pioneering work highlighted the importance of interpreting  
61 local motion of body parts by using gross motion tests within a broader functional system  
62 [32]. Polyarticular motion could therefore help to understand dysfunction and guide  
63 treatment. This is of major importance for education and research in osteopathic healthcare  
64 [20, 33, 34].

65 An interesting joint to test this principle is the temporomandibular joint. Some preliminary  
66 studies have reported that osteopathic care could decrease significantly cervical spine and/or  
67 temporomandibular joint pain [35–39] even if the rationale and mechanics by which  
68 osteopathic care may decrease bruxism remains unclear. Previous authors have suggested that  
69 osteopathic care could increase spine range of motion [40–43] but few studies have focused  
70 on functional assessments on patients with bruxism. This is probably due to the difficulty in  
71 objectifying dynamic motion without impeding the movement itself [20, 44]. Detailed range  
72 of motion analysis may nevertheless help identify specific patterns of movement alterations  
73 that are not easy to identify with other means of measurement. This has now become possible  
74 with new methodologies developed in biomechanics and human movement analysis [42, 45,  
75 46]. Video capture systems make it possible to evaluate motion in a constraint-free  
76 environment [37, 47, 48].

77 However, experimental observations are lacking to support the use of such analysis in clinical  
78 settings. Motion analysis is expensive, complex, and time-consuming making it difficult to  
79 apply in pragmatic clinical trials. However, the applications drawn from motion analysis  
80 could bring a better understanding of assessment procedures used in usual care and improve  
81 functional global assessment [49–53].

82 This study aims to investigate whether motion analysis is capable of detecting subtle changes  
83 in jaw and cervical motion in a reliable way when comparing OMT to sham therapy and  
84 identifying which outcome is best as primary outcome.

85

## 86 **METHODS**

### 87 *Trial design*

88 This study consisted of a pilot monocentric 1:1 randomised parallel trial on symptomatic and  
89 asymptomatic students. It explores the usefulness of motion analysis for future phase I and II  
90 clinical trials. Approval for this study was obtained from the institution's ethical and scientific  
91 board of XX. The study was conducted in accordance with the amended Declaration of  
92 Helsinki.

93

### 94 *Participants, randomization and allocation*

95 Recruitment of participants was conducted through an online questionnaire sent to all 314  
96 students from the Institute. Answers were collected from 124 osteopathic students.

97 Inclusion criteria were (1) being aged between 18 and 35 years, (2) being a student at the IO-  
98 RB, (3) having no musculoskeletal disorders reported in the cervical spine or the jaw, (4) and  
99 for the bruxism group, presenting chronic bruxism for more than a year. Exclusion criteria for  
100 both groups were: (1) having dental or orthodontic treatment in progress, (2) recent tooth

101 extraction, (3) known disc-condyle disunion, (4) bite splints, (5) orthognathic devices or (6)  
102 recent direct trauma.

103 Self-reported bruxism was not evaluated other than with the questionnaire on symptoms.

104 Symptoms related to TMJ disorders were also ruled out.

105 Participants received written and oral instructions about the intervention, test protocol, and

106 possible risks and benefits of the study. Students were told that different manual treatment

107 approaches were to be compared without specifically mentioning one of them to be sham.

108 This was necessary to avoid students discussing their treatment and guessing their allocation.

109 Once data collection was over, students were informed of the true nature of both groups.

110 Written informed consent was obtained from all participants before their inclusion in the

111 study.

112 All participants agreed to avoid other forms of manual treatment during their follow-up and if

113 required to notify this protocol deviation to investigators. Participants in both group bruxism

114 or no-bruxism were randomly allocated in a 1:1 ratio to two sub-groups OMT (Treated

115 Group) or sham treatment (Control Group) using a random sequence of blocks of size 4

116 generated by R. The study flowchart is presented in Figure 1. Allocation was then attributed

117 following the order of responses to the first online questionnaire. A staff member then

118 prepared the material for the treating osteopaths. Allocation was revealed to the osteopaths on

119 the arrival of each patient when opening each folder.

120

### 121 *Interventions*

122 OMT consisted of two treatment sessions (45') separated by seven days that were

123 personalized and included patient history taking, osteopathic diagnostic assessment and OMT.

124 Participants in the treatment group were randomly allocated to one of six osteopaths with over

125 10 years of practice experience. OMT was tailored for the patient by combining gentle



126 techniques on areas of restriction consisting of articulatory techniques, myofascial release  
127 techniques, functional techniques and visceral and cranial techniques, etc. The entire body  
128 was included in the osteopathic evaluation and treatment with special attention to the head,  
129 jaw and cervico-thoracic areas. Despite some expected variation in their application by  
130 different practitioners, all the techniques used were familiar to most recently trained  
131 osteopathic practitioners and taught in all French institutions.

132 Sham intervention (45') included patient history taking, osteopathic diagnostic assessment  
133 and two different protocols of three sham manual techniques pseudo-randomly assigned to  
134 each participant in order to reproduce, as similar as possible, the contextual variables of the  
135 sessions [54]. The sham protocol included palpation and tissue mobilisation that was  
136 predefined and targeted to specific regions without intent to change motion. All details about  
137 OMT and sham treatment interventions are reported in Table 1 using TIDieR-Placebo  
138 guidelines [55].

139

#### 140 *Outcomes*

141 All participants were assessed four times; first at baseline, then immediately after the first  
142 session, then seven days after the first session, and finally immediately after the second  
143 session. A research team member who was not involved with the interventions and was  
144 blinded to allocations was responsible for collecting all the baseline measures and follow-up  
145 outcomes.

146 The chosen motion outcomes of interest were the lateral jaw range of motion, jaw opening,  
147 cervical rotation and side-bending after the 1st and 2nd treatment, and one week after the first  
148 treatment. This was done through a video-based system developed for this study. Participants  
149 were equipped with 15 body landmarks indexed in Figure 2. Markers trajectories were

150 obtained from three sport cameras (Gopro Hero7Black, Gopro Hero6, Gopro Hero5) placed  
151 around the participant. The experimental setup was illustrated in Figure 3.

152 To evaluate the cervical spinal range of motion, participants were instructed to perform three  
153 trials of active maximal side-bending and rotation on each side (right and left). To evaluate  
154 jaw range of motion, students were also asked to perform three trials of active open/close and  
155 right and left lateral movement of the jaw. A randomized sequence of functional active  
156 movement of cervical and jaw movement was proposed for all students. Kinovea® software  
157 (v0.8.15) was used to analyse the experimental data and to compute the range of motion of the  
158 cervical spine (side, rotation) and the temporomandibular joint (lateral and opening movement  
159 of the jaw).

160

#### 161 *Blinding*

162 The researchers involved in the evaluation procedures had no access to the allocation of the  
163 participants. All participants were blinded to group assignment.

164

#### 165 *Statistical methods*

166 Outliers were defined for each measure and identified. These were most often related to  
167 misreading of motion markers which had to be manually framed. Such errors were corrected.  
168 Reliability of measures was evaluated using a one-way random-effect model with absolute  
169 agreement to calculate intraclass coefficient (ICC) for individual measures before taking their  
170 mean. After verifying that the range of motion was similar between the left and right side, a  
171 single outcome was summarized by adding ROM from the left to the right side. Baseline  
172 comparison between OMT intervention group and the sham group was compared using  
173 Student T-test. Linear regression was used to measure between-group differences at follow-up  
174 adjusting for baseline values. All analysis were intention-to-treat. Correlation between

175 outcomes was using Pearson correlation coefficients. Differences between students with or  
176 without bruxism were evaluated adding an interaction term in the logistic regression. The  
177 interaction term identified those who were both in the intervention arm and had symptoms. In  
178 other terms, the logistic regression modelled the added effects of treatment in participants  
179 with bruxism. Significance level was set at  $p < 0.05$ . No adjustments were made for multiple  
180 testing. Sensitivity analysis was done post-hoc to verify that results were consistent even after  
181 adjusting for baseline imbalance.

182

## 183 **RESULTS**

### 184 *Participants and baseline values*

185 A total of 48 participants were recruited from a XX osteopathic educational institution, the  
186 XX, between September and October 2019. Two participants did not attend their appointment  
187 (for medical reasons outside the context of the study) and were excluded from further  
188 analysis, resulting in a total sample of 23 participants in the bruxism group and 23 participants  
189 in the no-bruxism group. All participants received allocated treatments. No major protocol  
190 deviation was reported.

191 Most participants were female (34/46; 73.9%), their age ranged from 18 to 25 years, their  
192 BMI was of 22.4 on average (ranging from 18.3 to 32.4 kg/m<sup>2</sup>). Details on baseline values for  
193 each group are provided in Table 2. Except for cervical rotation in the group with bruxism  
194 ( $p = 0.012$ ), all other measures were well balanced between groups ( $p > 0.05$ ).

195

### 196 *Reliability*

197 Repeated measures of joint motion at baseline showed high levels of reliability. Individual  
198 measures had an ICC of 0.953 (CI95% 0.925 to 0.972) for jaw lateral movement, an ICC of

199 0.975 (CI95% 0.959 to 0.985) for jaw opening, an ICC of 0.975 (CI95% 0.959 to 0.985) for  
200 cervical side-bending, and an ICC of 0.985 (CI95% 0.975 to 0.990) for cervical rotation.

201

202

### 203 *Objectivation of OMT on jaw lateral movement*

204 One week after treatment, compared to sham, OMT treatment had a significant effect on  
205 increasing lateral jaw ROM (+3.3°; CI95% 0.6 to 5.9°; p=0.018) on participants with bruxism  
206 (Table 3). This effect was absent in the group without bruxism (-0.4°; CI95% -2.4 to 1.7;  
207 p=0.720). Effects of treatment were restricted to those having symptoms. Having bruxism was  
208 determinant for OMT to have effects on jaw lateral movement in the studied population  
209 (interaction test shows superiority of 4.1°, CI95% 0.9 to 7.2, p=0.012). These results  
210 remained similar even after adjustment for baseline imbalance.

211

### 212 *Effects on other ROMs*

213 For students with bruxism, at one week, OMT had a significant effect over sham intervention  
214 on cervical rotation ROM (+12.0°; CI95% 4.7° to 19.3°, p=0.003), but not on jaw opening or  
215 cervical side-bending (Table 3). Similar results were observed for short term effects,  
216 immediately after the first treatment with lower magnitudes for cervical rotation (+7.8°,  
217 p<0.001) and significant effects for cervical side-bending (+5.2°, p=0.045). Following the  
218 second treatment, effects were significant for all parameters (Table 3).

219 For students without bruxism, compared to sham intervention, at one week there were no  
220 effects on jaw opening (+0.4°; p=0.821), cervical side-bending (+0.6°, p=0.851) or cervical  
221 rotation (+6.4°, p=0.09). This was also the case in the short term, immediately after treatment  
222 and immediately after the second treatment except for cervical rotation which was increased  
223 by 10.4° in the OMT group (CI95% 1.7 to 10.0; p=0.021).

224

225 *Correlations between parameters*

226 Changes over time at one week were correlated between jaw and cervical ROM. Students that  
227 gained in lateral jaw movement also gained in cervical side-bending ( $\rho=0.313$ ,  $p=0.036$ ) and  
228 cervical rotation ( $\rho=0.378$ ,  $p=0.010$ ). These same correlations became stronger for students  
229 with bruxism (cervical side-bending:  $\rho=0.595$ ,  $p=0.003$  ; cervical rotation:  $\rho=0.440$ ,  $p=0.036$ )  
230 and optimal for cervical side-bending in students with bruxism and OMT ( $\rho=0.640$ ,  $p=0.018$ ).  
231 In this same sub-population, there was also a correlation between gain in cervical rotation and  
232 reduced jaw opening ( $\rho=-0.567$ ,  $p=0.043$ ) that was however absent in other students.

233

234 *Efficacy of blinding*

235 At the 15-day follow-up, participants were asked whether they believed they were in the  
236 active or sham group. Proportion of those believing they were in the active treatment group  
237 was similar in the OMT group (11/25; 44%) and in the sham group (7/20; 35%;  $p=0.760$ ).

238

239 *Adverse events*

240 Adverse events were monitored and self-reported one week after each treatment. No adverse  
241 events were reported by the participants.

242

243 **DISCUSSION**

244 The main finding of this study was that a video-based approach can objectively identify  
245 effects of OMT on cervical and jaw range of motion during two sessions of osteopathic care.  
246 Results showed that motion analysis made it possible to show that osteopathic manual care, as  
247 compared to sham, induces increased cervical and jaw ROM. Results suggest lateral jaw  
248 movement to be a good choice for primary outcome in studies evaluating effects of OMT on

249 patients with bruxism. This pilot study also suggests blinding to be feasible using sham  
250 treatment on students. Finally, the gain in mobility was correlated between jaw lateral  
251 movement and cervical side-bending supporting our initial hypothesis of the interest of  
252 investigating movement over more than one joint.

253 The methodology developed in this study allowed to observe and analyse, through different  
254 time intervals measurements, the effect of the osteopathic manual care over time in an  
255 outstanding reliable way ( $ICC > 0.95$ ). The consistency of results over-time also suggests that  
256 treatment effects are conserved over at least seven days and could be emphasized by a second  
257 treatment session (Figure 4). Contrary to clinical motion tests, motion analysis can be an  
258 efficient and objective way to evaluate functional changes in movement following osteopathic  
259 manual care.

260 However, our results should be interpreted with caution. Joint range of motion is by no means  
261 the only mechanism involved in bruxism and several etiological factors (psychosocial,  
262 anatomical, and/or neuromuscular factors) also need to be explored during patient  
263 management. Improved range of motion may be simply a surrogate of improved motor  
264 control. Functional motion disorders have been shown to be closely related to alteration of  
265 motor control, reduced discriminatory sensation, catastrophization, fear-avoidance, and loss  
266 of self-confidence [56–58].

267 However, even if our results support the hypothesis that OMT could alter motor control  
268 during movement, they do not make it possible to know whether these changes represent any  
269 meaningful change for patients (i.e. reduced jaw tension, reduced pain). Range of motion  
270 often investigates movements that are most often not done naturally. The underlying  
271 theoretical construct linking range of motion with daily symptoms infers that the underlying  
272 changes also affect movement before reaching physiological limits. This assumption was not  
273 tested. This would require collecting more descriptive and tangible evidences of individual

274 motor behaviours, not only in a traditional structural model of articular dysfunction but during  
275 specific functional motion tests [26]. Also, additional determinants could be explored during  
276 functional motion-tests both with instrumental approaches (electromyography – jaw muscle  
277 activity) and non-instrumental approaches (self-reported - perceived pain, stress levels and  
278 impact on daily life).

279

#### 280 *Practical applications for education and research*

281 One of the challenges of education is to find a way to facilitate the transition from academic  
282 learning to training for their future profession but also to research [59]. Biomechanics has  
283 been introduced as an official teaching unit in the education of osteopathic students since  
284 2014 in France [60]. The challenge is to apply both anatomical/physiological bases and  
285 mechanical concepts (mathematics and physics) to observe/describe/measure human  
286 movement from a number of different applications that cut across the sub-areas of movement  
287 sciences (sport, ergonomics, injury, clinical rehabilitation, etc.) [61, 62]. Additionally, new  
288 teaching innovative methodologies to evaluate human movement (Wii Balance Board  
289 platform, Kinect, smartphone applications, etc.) were proposed to facilitate the  
290 comprehension of biomechanics laws/applications and to make it more “touchable” and  
291 inform students about these tools and their limits [63, 64]. The challenge is also to educate  
292 future osteopaths in the use of objective tools to evaluate their treatments in order to promote  
293 research in osteopathy and to transfer knowledge to education and clinical practice [20, 65,  
294 66]. In this sense, a large number of research themes must be proposed involving students and  
295 educators to continue building evidence by validating or disproving the knowledge or beliefs  
296 related to osteopathic care [3–6, 34]. Future challenges for the profession are to develop  
297 collaborations with other disciplines to create new knowledge and the assessment of the  
298 effectiveness of osteopathic manual care in the light of scientific methods but also to associate

299 applied biomechanics and neurosciences to propose new findings in the impact of osteopathic  
300 healthcare [34, 67].

301

### 302 *Limitations*

303 This study involved a modest cohort of 46 students (divided into 4 experimental groups), it  
304 would be interesting for future phase 2 and 3 clinical trials to use a similar methodology  
305 measuring ROM on a larger population with a follow-up by combining, it with other  
306 measurement tools (Patient Reported Outcome Measures, validated questionnaires,  
307 electromyography, etc.) to assess the impact of the global effect of osteopathic care on  
308 behaviour.

309 The study also might be limited in external validity given it targets a specific population  
310 particularly concerned by bruxism [7, 9, 10]. Slight differences in treatment approaches  
311 between osteopaths cannot be ruled out. All six osteopaths however work in the same school  
312 clinic and are used to follow similar approaches. Nevertheless, future studies need to consider  
313 training osteopaths to assure they deliver similar treatments and include fidelity analysis to  
314 verify if treatment was delivered as planned. Even if blinding was assured, the students'  
315 response to treatment could be influenced by their familiarity with the discipline and  
316 communication between students.

317 We collected motion with three sport cameras but not really in 3D with an optoelectronic  
318 system for example. However, after comparing the data from this study with previous authors  
319 who have established an important database on cervical and mandibular kinematics from 22  
320 experimental studies using recognized systems, it appears that the data obtained are close to  
321 the standards they established [68, 69]. In this way, we observed in this pilot study, the effect  
322 of OMT only in maximal ROM which focuses on assessing the patient's maximum capacity to  
323 perform selected active movements. In order to assess dynamic functional behaviour, it could



324 be useful to track/estimate all the 3D kinematic of each degree of freedom to explore the  
325 evolution of the pattern of motion during the functional assessment before and after OMT.  
326 This appears to be a better way to explore motion behaviour which is used for the quantified  
327 analysis of walking, running or rowing for example [70–73]. A potential limitation to future  
328 use of motion analysis in clinical trials is the availability and access to sophisticated material  
329 and skilled personnel making it possible to acquire meaningful data. Therefore, future studies  
330 with optoelectronic, medical system imagery or inertial sensors are needed to go further with  
331 the data collection/analysis but also to confirm the benefits of the treatment and the  
332 assessment method [74–77]. Finally, the subjectivity of active voluntary movements could  
333 have introduced social desirability bias to the observed improvements in ROM due to OMT.  
334 New insights on interoceptive perception and the eventual role of osteopathic care in helping  
335 solve misrepresentation of one's body perception and movement are promising to the  
336 profession [67, 78].

337

## 338 **CONCLUSION**

339 This study highlighted that a video-based approach may allow analysing musculoskeletal  
340 function of the jaw and cervical spine before and after OMT. Motion analysis can reveal  
341 improvements of cervical and jaw ROM following OMT in osteopathic students with bruxism  
342 compared to sham treatment. A longitudinal investigation with a larger sample is needed to  
343 confirm the benefits of the treatment and the assessment method. These outcomes are  
344 promising for future studies investigating the role of osteopathic care in preventing  
345 musculoskeletal conditions in people with bruxism.

346 This approach could be implemented as an additional tool to objectify the effect of  
347 osteopathic healthcare and also to the global advancement of the profession in thriving,  
348 growing osteopathic research culture necessary in the contemporary health care landscape.

349  
350  
351

Journal Pre-proof

## 352 REFERENCES

- 353 [1] Lobbezoo, F.; Ahlberg, J.; Glaros, A. G.; Kato, T.; Koyano, K.; Lavigne, G. J.; de Leeuw, R.;  
354 Manfredini, D.; Svensson, P.; Winocur, E. Bruxism Defined and Graded: An International  
355 Consensus. *J. Oral Rehabil.*, **2013**, *40* (1), 2–4. <https://doi.org/10.1111/joor.12011>.
- 356 [2] Lobbezoo, F.; Ahlberg, J.; Raphael, K. G.; Wetselaar, P.; Glaros, A. G.; Kato, T.; Santiago, V.;  
357 Winocur, E.; De Laat, A.; De Leeuw, R.; et al. International Consensus on the Assessment of  
358 Bruxism: Report of a Work in Progress. *J. Oral Rehabil.*, **2018**, *45* (11), 837–844.  
359 <https://doi.org/10.1111/joor.12663>.
- 360 [3] Martinot, J.-B.; Borel, J.-C.; Le-Dong, N.-N.; Silkoff, P. E.; Denison, S.; Gozal, D.; Pépin, J.-L.  
361 Bruxism Relieved Under CPAP Treatment in a Patient With OSA Syndrome. *Chest*, **2020**, *157*  
362 (3), e59–e62. <https://doi.org/10.1016/j.chest.2019.07.032>.
- 363 [4] Martynowicz, H.; Smardz, J.; Michalek-Zrabkowska, M.; Gac, P.; Poreba, R.; Wojakowska, A.;  
364 Mazur, G.; Wieckiewicz, M. Evaluation of Relationship Between Sleep Bruxism and Headache  
365 Impact Test-6 (HIT-6) Scores: A Polysomnographic Study. *Front. Neurol.*, **2019**, *10*.  
366 <https://doi.org/10.3389/fneur.2019.00487>.
- 367 [5] Ohlmann, B.; Waldecker, M.; Leckel, M.; Bömicke, W.; Behnisch, R.; Rammelsberg, P.;  
368 Schmitter, M. Correlations between Sleep Bruxism and Temporomandibular Disorders. *J. Clin.*  
369 *Med.*, **2020**, *9* (2), 611. <https://doi.org/10.3390/jcm9020611>.
- 370 [6] Yap, A. U.; Chua, A. P. Sleep Bruxism: Current Knowledge and Contemporary Management. *J.*  
371 *Conserv. Dent. JCD*, **2016**, *19* (5), 383–389. <https://doi.org/10.4103/0972-0707.190007>.
- 372 [7] Cavallo, P.; Carpinelli, L.; Savarese, G. Perceived Stress and Bruxism in University Students.  
373 *BMC Res. Notes*, **2016**, *9* (1), 514. <https://doi.org/10.1186/s13104-016-2311-0>.
- 374 [8] Manfredini, D.; Winocur, E.; Guarda-Nardini, L.; Paesani, D.; Lobbezoo, F. Epidemiology of  
375 Bruxism in Adults: A Systematic Review of the Literature. *J. Orofac. Pain*, **2013**, *27* (2), 99–  
376 110. <https://doi.org/10.11607/jop.921>.
- 377 [9] Soares, L. G.; Costa, I. R.; Júnior, J. dos S. B.; Cerqueira, W. S. B.; Oliveira, E. S. de; Oliveira,  
378 D. W. D. de; Gonçalves, P. F.; Glória, J. C. R.; Tavano, K. T. A.; Flecha, O. D. Prevalence of  
379 Bruxism in Undergraduate Students. *CRANIO®*, **2017**, *35* (5), 298–303.  
380 <https://doi.org/10.1080/08869634.2016.1218671>.
- 381 [10] Wetselaar, P.; Vermaire, E. (J H. ); Lobbezoo, F.; Schuller, A. A. The Prevalence of Awake  
382 Bruxism and Sleep Bruxism in the Dutch Adult Population. *J. Oral Rehabil.*, **2019**, *46* (7), 617–  
383 623. <https://doi.org/10.1111/joor.12787>.
- 384 [11] Gouw, S.; Frowein, A.; Braem, C.; Wijer, A. de; Creugers, N. H. J.; Pasman, J. W.; Doorduyn, J.;  
385 Kalaykova, S. I. Coherence of Jaw and Neck Muscle Activity during Sleep Bruxism. *J. Oral*  
386 *Rehabil.*, **2020**, *47* (4), 432–440. <https://doi.org/10.1111/joor.12932>.
- 387 [12] Armijo Olivo, S.; Magee, D. J.; Parfitt, M.; Major, P.; Thie, N. M. R. The Association between  
388 the Cervical Spine, the Stomatognathic System, and Craniofacial Pain: A Critical Review. *J.*  
389 *Orofac. Pain*, **2006**, *20* (4), 271–287.
- 390 [13] Armijo-Olivo, S.; Magee, D. Cervical Musculoskeletal Impairments and Temporomandibular  
391 Disorders. *J. Oral Maxillofac. Res.*, **2013**, *3* (4). <https://doi.org/10.5037/jomr.2012.3404>.
- 392 [14] Olivo, S. A.; Fuentes, J.; Major, P. W.; Warren, S.; Thie, N. M. R.; Magee, D. J. The Association  
393 between Neck Disability and Jaw Disability. *J. Oral Rehabil.*, **2010**, *37* (9), 670–679.  
394 <https://doi.org/10.1111/j.1365-2842.2010.02098.x>.
- 395 [15] Piekartz, H. von; Rösner, C.; Batz, A.; Hall, T.; Ballenberger, N. Bruxism, Temporomandibular  
396 Dysfunction and Cervical Impairments in Females – Results from an Observational Study.  
397 *Musculoskelet. Sci. Pract.*, **2020**, *45*, 102073. <https://doi.org/10.1016/j.msksp.2019.102073>.

- 398 [16] Thomson, O. P.; Petty, N. J.; Moore, A. P. Osteopaths' Professional Views, Identities and  
399 Conceptions – A Qualitative Grounded Theory Study. *Int. J. Osteopath. Med.*, **2014**, *17* (3),  
400 146–159. <https://doi.org/10.1016/j.ijosm.2013.12.002>.
- 401 [17] Vaucher, P.; Macdonald, R. J. D.; Carnes, D. The Role of Osteopathy in the Swiss Primary  
402 Health Care System: A Practice Review. *BMJ Open*, **2018**, *8* (8).  
403 <https://doi.org/10.1136/bmjopen-2018-023770>.
- 404 [18] Bill, A.-S.; Dubois, J.; Pasquier, J.; Burnand, B.; Rodondi, P.-Y. Osteopathy in the French-  
405 Speaking Part of Switzerland: Practitioners' Profile and Scope of Back Pain Management. *PLOS*  
406 *ONE*, **2020**, *15* (5), e0232607. <https://doi.org/10.1371/journal.pone.0232607>.
- 407 [19] Morin, C.; Aubin, A. Primary Reasons for Osteopathic Consultation: A Prospective Survey in  
408 Quebec. *PLoS One*, **2014**, *9* (9), e106259. <https://doi.org/10.1371/journal.pone.0106259>.
- 409 [20] Steel, A.; Foley, H.; Redmond, R. Person-Centred Care and Traditional Philosophies in the  
410 Evolution of Osteopathic Models and Theoretical Frameworks: Response to Esteves et Al. *Int. J.*  
411 *Osteopath. Med.*, **2020**, *0* (0). <https://doi.org/10.1016/j.ijosm.2020.03.001>.
- 412 [21] OIA. *Osteopathy and Osteopathic Practice; A Global View of Practice, Patients, Education and*  
413 *the Contribution to Healthcare Delivery*; Osteopathic International Alliance: Chicago, 2013.
- 414 [22] World Health Organisation. *Benchmarks for Training in Traditional /Complementary and*  
415 *Alternative Medicine: Benchmarks for Training in Osteopathy*; WHO: Geneva, 2010.
- 416 [23] Basile, F.; Scionti, R.; Petracca, M. Diagnostic Reliability of Osteopathic Tests: A Systematic  
417 Review. *Int. J. Osteopath. Med.*, **2017**, *25*, 21–29. <https://doi.org/10.1016/j.ijosm.2017.03.004>.
- 418 [24] Fryer, G. Somatic Dysfunction: An Osteopathic Conundrum. *Int. J. Osteopath. Med.*, **2016**, *22*,  
419 52–63. <https://doi.org/10.1016/j.ijosm.2016.02.002>.
- 420 [25] Vaucher, P. Questioning the Rationality of Clinical Osteopathic Tests : Future Perspectives for  
421 Research. *Mains Libr.*, **2016**, *33* (1), 33–37.
- 422 [26] Johnston, W. L.; Vorro, J. A Call for Osteopathic Descriptive Research: Use of a Functional  
423 Model to Distinguish Segmental Motion Behavior. *J. Osteopath. Med.*, **2003**, *6* (1), 30–33.  
424 [https://doi.org/10.1016/S1443-8461\(03\)80007-2](https://doi.org/10.1016/S1443-8461(03)80007-2).
- 425 [27] DiGiovanna, E. L.; Schiowitz, S.; Dowling, D. J. *An Osteopathic Approach to Diagnosis and*  
426 *Treatment*; Lippincott Williams & Wilkins, 2005.
- 427 [28] Chenaut, P.; Ménard, M.; Vaucher, P.; Lancelot, L.; Bideau, B.; Bourgin, M. Biomechanical  
428 Analysis of the Lumbar-Pelvic-Femoral Complex during the One- Sided Tilt Test: A Pilot Study  
429 in Triathletes. *Comput. Methods Biomech. Biomed. Engin.*, **2019**, *22*, S1–S393.  
430 <https://doi.org/10.1080/10255842.2020.1714921>.
- 431 [29] Ménard, M.; Vaucher, P.; Chenaut, P.; Lancelot, L.; Francois, L.; Bourgin, M.; Bideau, B.  
432 Analyse biomécanique du complexe lombo-pelvi- fémoral lors du test d'inclinaison unilatérale  
433 du bassin : étude pilote sur des triathlètes. *Mains Libr.*, **2019**, No. 3, 19–26.
- 434 [30] Retailleau, M.; Colloud, F. New Insights into Lumbar Flexion Tests Based on Inverse and Direct  
435 Kinematic Musculoskeletal Modeling. *J. Biomech.*, **2020**, 109782.  
436 <https://doi.org/10.1016/j.jbiomech.2020.109782>.
- 437 [31] Johnston, W. *Functional Methods*; American Academy Osteopathy: Indianapolis, Ind., 2004.
- 438 [32] Osteopathy, A. A. of; and clinical investigator. The Johnston Academy Yearbook honors  
439 William L. Johnston, D. O. *Scientific Contributions of William L. Johnston, DO, FAAO*; FAAO  
440 Myron C. Beal, D. O., Ed.; Indianapolis, IN., 1998.
- 441 [33] Esteves, J. E.; Zegarra-Parodi, R.; van Dun, P.; Cerritelli, F.; Vaucher, P. Models and  
442 Theoretical Frameworks for Osteopathic Care – A Critical View and Call for Updates and  
443 Research. *Int. J. Osteopath. Med.*, **2020**, *35*, 1–4. <https://doi.org/10.1016/j.ijosm.2020.01.003>.

- 444 [34] Ménard, M.; Draper-Rodi, J.; Merdy, O.; Wagner, A.; Tavernier, P.; Jacquot, E.; Mhadhbi, H.  
 445 Finding a Way between Osteopathic Principles and Evidence-Based Practices: Response to  
 446 Esteves et Al. *Int. J. Osteopath. Med.*, **2020**, S1746068920301383.  
 447 <https://doi.org/10.1016/j.ijosm.2020.07.006>.
- 448 [35] Cuccia, A. M.; Caradonna, C.; Annunziata, V.; Caradonna, D. Osteopathic Manual Therapy  
 449 versus Conventional Conservative Therapy in the Treatment of Temporomandibular Disorders:  
 450 A Randomized Controlled Trial. *J. Bodyw. Mov. Ther.*, **2010**, *14* (2), 179–184.  
 451 <https://doi.org/10.1016/j.jbmt.2009.08.002>.
- 452 [36] Gesslbauer, C.; Vavti, N.; Keilani, M.; Mickel, M.; Crevenna, R. Effectiveness of Osteopathic  
 453 Manipulative Treatment versus Osteopathy in the Cranial Field in Temporomandibular  
 454 Disorders – a Pilot Study. *Disabil. Rehabil.*, **2018**, *40* (6), 631–636.  
 455 <https://doi.org/10.1080/09638288.2016.1269368>.
- 456 [37] Manzotti, A.; Viganoni, C.; Lauritano, D.; Bernasconi, S.; Paparo, A.; Risso, R.; Nanussi, A.  
 457 Evaluation of the Stomatognathic System before and after Osteopathic Manipulative Treatment  
 458 in 120 Healthy People by Using Surface Electromyography. *Int. J. Environ. Res. Public Health*,  
 459 **2020**, *17* (9), 3250. <https://doi.org/10.3390/ijerph17093250>.
- 460 [38] Monaco, A.; Cozzolino, V.; Cattaneo, R.; Cutilli, T.; Spadaro, A. Osteopathic Manipulative  
 461 Treatment (OMT) Effects on Mandibular Kinetics: Kinesiographic Study. *Eur. J. Paediatr.*  
 462 *Dent.*, **2008**, *6*.
- 463 [39] Burns, D. K.; Wells, M. R. Gross Range of Motion in the Cervical Spine: The Effects of  
 464 Osteopathic Muscle Energy Technique in Asymptomatic Subjects. *JAOA*, **2006**, *106* (3), 6.
- 465 [40] Branney, J.; Breen, A. C. Does Inter-Vertebral Range of Motion Increase after Spinal  
 466 Manipulation? A Prospective Cohort Study. *Chiropr. Man. Ther.*, **2014**, *22* (1), 24.  
 467 <https://doi.org/10.1186/s12998-014-0024-9>.
- 468 [41] Fryer, G.; Ruszkowski, W. The Influence of Contraction Duration in Muscle Energy Technique  
 469 Applied to the Atlanto-Axial Joint. *J. Osteopath. Med.*, **2004**, *7* (2), 79–84.  
 470 [https://doi.org/10.1016/S1443-8461\(04\)80016-9](https://doi.org/10.1016/S1443-8461(04)80016-9).
- 471 [42] Ménard, M.; Vaucher, P.; Mhadhbi, H.; Bideau, B.; Bourgin, M. Modélisation du système  
 472 musculo-squelettique : Implications cliniques, prévention des blessures et perspectives pour la  
 473 recherche en ostéopathie. *Neurophysiol. Clin.*, **2019**, *49* (3), 258.  
 474 <https://doi.org/10.1016/j.neucli.2019.01.024>.
- 475 [43] Millan, M.; Leboeuf-Yde, C.; Budgell, B.; Descarreaux, M.; Amorim, M.-A. The Effect of  
 476 Spinal Manipulative Therapy on Spinal Range of Motion: A Systematic Literature Review.  
 477 *Chiropr. Man. Ther.*, **2012**, *20*, 23. <https://doi.org/10.1186/2045-709X-20-23>.
- 478 [44] Alvarez, G.; Solà, I.; Sitjà-Rabert, M.; Fort-Vanmeerhaeghe, A.; Gich, I.; Fernández, C.; Bonfill,  
 479 X.; Urrútia, G. A Methodological Review Revealed That Reporting of Trials in Manual Therapy  
 480 Has Not Improved over Time. *J. Clin. Epidemiol.*, **2020**, *121*, 32–44.  
 481 <https://doi.org/10.1016/j.jclinepi.2020.01.006>.
- 482 [45] Begon, M.; Lacouture, P. Modélisation Anthropométrique Pour Une Analyse Mécanique Du  
 483 Geste Sportif: Partie 1 : Modèles, Leurs Caractéristiques et Leur Validation. *Sci. Mot.*, **2005**, No.  
 484 *54*, 11–33. <https://doi.org/10.3917/sm.054.0011>.
- 485 [46] Begon, M.; Lacouture, P. Modélisation Anthropométrique Pour Une Analyse Mécanique Du  
 486 Geste Sportif.: Partie 2: Estimation Des Centres Articulaires et Détermination de La  
 487 Cinématique Du Squelette. *Sci. Mot.*, **2010**, No. *55*, 35–60. <https://doi.org/10.3917/sm.055.0035>.
- 488 [47] Ren, S. Biomechanical Effects of Cranio-Cervical Positions on Cervical Musculoskeletal  
 489 Disorders. **2017**.
- 490 [48] Salem, W. La colonne cervicale de la physiologie intersegmentaire tridimensionnelle à la  
 491 manipulation ostéopathique par haute vitesse basse amplitude études in vivo. **2013**.

- 492 [49] Balsalobre-Fernández, C.; Tejero-González, C. M.; del Campo-Vecino, J.; Bavaresco, N. The  
 493 Concurrent Validity and Reliability of a Low-Cost, High-Speed Camera-Based Method for  
 494 Measuring the Flight Time of Vertical Jumps. *J. Strength Cond. Res.*, **2014**, *28* (2), 528–533.  
 495 <https://doi.org/10.1519/JSC.0b013e318299a52e>.
- 496 [50] Bernardina, G. R. D.; Monnet, T.; Pinto, H. T.; Barros, R. M. L. de; Cerveri, P.; Silvatti, A. P.  
 497 Are Action Sport Cameras Accurate Enough for 3D Motion Analysis? A Comparison With a  
 498 Commercial Motion Capture System. *J. Appl. Biomech.*, **2017**, *35* (1), 80–86.  
 499 <https://doi.org/10.1123/jab.2017-0101>.
- 500 [51] Elwardany, S. H.; El-Sayed, W. H.; Ali, M. F. Reliability of Kinovea Computer Program in  
 501 Measuring Cervical Range of Motion in Sagittal Plane. *OALib*, **2015**, *02* (09), 1–10.  
 502 <https://doi.org/10.4236/oalib.1101916>.
- 503 [52] Guzmán-Valdivia, C. H.; Blanco-Ortega, A.; Oliver-Salazar, M. A.; Carrera-Escobedo, J. L.  
 504 Therapeutic Motion Analysis of Lower Limbs Using Kinovea. **2013**, *3* (2), 7.
- 505 [53] Puig-Diví, A.; Escalona-Marfil, C.; Padullés-Riu, J. M.; Busquets, A.; Padullés-Chando, X.;  
 506 Marcos-Ruiz, D. Validity and Reliability of the Kinovea Program in Obtaining Angles and  
 507 Distances Using Coordinates in 4 Perspectives. *PLOS ONE*, **2019**, *14* (6), e0216448.  
 508 <https://doi.org/10.1371/journal.pone.0216448>.
- 509 [54] Rossettini, G.; Carlino, E.; Testa, M. Clinical Relevance of Contextual Factors as Triggers of  
 510 Placebo and Nocebo Effects in Musculoskeletal Pain. *BMC Musculoskelet. Disord.*, **2018**, *19*.  
 511 <https://doi.org/10.1186/s12891-018-1943-8>.
- 512 [55] Howick, J.; Webster, R. K.; Rees, J. L.; Turner, R.; Macdonald, H.; Price, A.; Evers, A. W. M.;  
 513 Bishop, F.; Collins, G. S.; Bokelmann, K.; et al. TIDieR-Placebo: A Guide and Checklist for  
 514 Reporting Placebo and Sham Controls. *PLOS Med.*, **2020**, *17* (9), e1003294.  
 515 <https://doi.org/10.1371/journal.pmed.1003294>.
- 516 [56] O’Sullivan, P. Diagnosis and Classification of Chronic Low Back Pain Disorders: Maladaptive  
 517 Movement and Motor Control Impairments as Underlying Mechanism. *Man. Ther.*, **2005**, *10* (4),  
 518 242–255. <https://doi.org/10.1016/j.math.2005.07.001>.
- 519 [57] Wernli, K.; Tan, J.-S.; O’Sullivan, P.; Smith, A.; Campbell, A.; Kent, P. Does Movement  
 520 Change When Low Back Pain Changes? A Systematic Review. *J. Orthop. Sports Phys. Ther.*,  
 521 **2020**, 1–48. <https://doi.org/10.2519/jospt.2020.9635>.
- 522 [58] Lin, I.; Wiles, L.; Waller, R.; Caneiro, J. P.; Nagree, Y.; Straker, L.; Maher, C. G.; O’Sullivan, P.  
 523 P. B. Patient-Centred Care: The Cornerstone for High-Value Musculoskeletal Pain Management.  
 524 *Br. J. Sports Med.*, **2020**, *54* (21), 1240–1242. <https://doi.org/10.1136/bjsports-2019-101918>.
- 525 [59] Launay, F.; Ménard, M.; Bourgin, M.; Mhadhbi, H.; Sutre, F.; Draper-Rodi, J. Impact of  
 526 Different Types of Revision Materials on the Learning of Musculoskeletal Techniques. *Int. J.*  
 527 *Osteopath. Med.*, **2020**, *0* (0). <https://doi.org/10.1016/j.ijosm.2020.08.003>.
- 528 [60] *Décret N° 2014-1505 Du 12 Décembre 2014 Relatif à La Formation En Ostéopathie*; 2014.
- 529 [61] Hamill, J. Biomechanics Curriculum: Its Content and Relevance to Movement Sciences. *Quest*,  
 530 **2007**, *59* (1), 25–33. <https://doi.org/10.1080/00336297.2007.10483533>.
- 531 [62] Wallace, B.; Knudson, D. The Effect of Course Format on Student Learning in Introductory  
 532 Biomechanics Courses That Utilise Low-Tech Active Learning Exercises. *Sports Biomech.*,  
 533 **2020**, *0* (0), 1–10. <https://doi.org/10.1080/14763141.2020.1830163>.
- 534 [63] Clark, R. A.; Mentiplay, B. F.; Pua, Y.-H.; Bower, K. J. Reliability and Validity of the Wii  
 535 Balance Board for Assessment of Standing Balance: A Systematic Review. *Gait Posture*, **2018**,  
 536 *61*, 40–54. <https://doi.org/10.1016/j.gaitpost.2017.12.022>.
- 537 [64] Keogh, J. W. L.; Cox, A.; Anderson, S.; Liew, B.; Olsen, A.; Schram, B.; Furness, J. Reliability  
 538 and Validity of Clinically Accessible Smartphone Applications to Measure Joint Range of

- 539 Motion: A Systematic Review. *PloS One*, **2019**, *14* (5), e0215806.  
540 <https://doi.org/10.1371/journal.pone.0215806>.
- 541 [65] Browning, S. Teaching Osteopathic Students Technique; Using Research to Identify Good  
542 Teaching Practice. *Int. J. Osteopath. Med.*, **2010**, *13* (2), 70–73.  
543 <https://doi.org/10.1016/j.ijosm.2009.10.004>.
- 544 [66] Fryer, G. Teaching Critical Thinking in Osteopathy – Integrating Craft Knowledge and  
545 Evidence-Informed Approaches. *Int. J. Osteopath. Med.*, **2008**, *11* (2), 56–61.  
546 <https://doi.org/10.1016/j.ijosm.2008.02.005>.
- 547 [67] Esteves, J. E.; Zegarra-Parodi, R.; Dun, P. van; Cerritelli, F.; Vaucher, P. Models and  
548 Theoretical Frameworks for Osteopathic Care – A Critical View and Call for Updates and  
549 Research. *Int. J. Osteopath. Med.*, **2020**, *35*, 1–4. <https://doi.org/10.1016/j.ijosm.2020.01.003>.
- 550 [68] Koepfel, T. Analyse cinématique de l'appareil manducateur humain : constitution d'une base de  
551 données de sujets asymptotiques et comparaison avec sujets à dysfonction. phdthesis,  
552 Université de Lorraine, 2017.
- 553 [69] Boussion, L. Étude cinématique tridimensionnelle du rachis cervical. Comparaison entre sujets  
554 Asymptotiques et pathologiques. phdthesis, Université Claude Bernard - Lyon I, 2008.
- 555 [70] Chehab, E. F.; Andriacchi, T. P.; Favre, J. Speed, Age, Sex, and Body Mass Index Provide a  
556 Rigorous Basis for Comparing the Kinematic and Kinetic Profiles of the Lower Extremity during  
557 Walking. *J. Biomech.*, **2017**, *58*, 11–20. <https://doi.org/10.1016/j.jbiomech.2017.04.014>.
- 558 [71] Ménard, M.; Sorel, A.; Boumpoutou, R.; Kulpa, R.; Kerhervé, H. A.; Bideau, B. A  
559 Musculoskeletal Modelling Approach of the Assessment of the Risk of Hamstring Injuries in  
560 Professional Soccer Players: A Pilot Study. *Sci. Med. Footb.*, **2020**.  
561 <https://doi.org/10.1080/24733938.2020.1786765>.
- 562 [72] Retailleau, M.; Domalain, M.; Ménard, M.; Colloud, F. Kinematics of the Lumbar Muscles in  
563 Rowing: A Preliminary Study. *Comput. Methods Biomech. Biomed. Engin.*, **2017**, *20* (sup1),  
564 173–174. <https://doi.org/10.1080/10255842.2017.1382918>.
- 565 [73] Riley, P. O.; Paolini, G.; Della Croce, U.; Paylo, K. W.; Kerrigan, D. C. A Kinematic and  
566 Kinetic Comparison of Overground and Treadmill Walking in Healthy Subjects. *Gait Posture*,  
567 **2007**, *26* (1), 17–24. <https://doi.org/10.1016/j.gaitpost.2006.07.003>.
- 568 [74] Cazzola, D.; Holsgrove, T. P.; Preatoni, E.; Gill, H. S.; Trewartha, G. Cervical Spine Injuries: A  
569 Whole-Body Musculoskeletal Model for the Analysis of Spinal Loading. *PLOS ONE*, **2017**, *12*  
570 (1), e0169329. <https://doi.org/10.1371/journal.pone.0169329>.
- 571 [75] Plochanski, M.; Lindstroem, R.; Lindstroem, C. F.; Østergaard, L. R. Motion Analysis of the  
572 Cervical Spine during Extension and Flexion: Reliability of the Vertebral Marking Procedure.  
573 *Med. Eng. Phys.*, **2018**, *61*, 81–86. <https://doi.org/10.1016/j.medengphy.2018.07.010>.
- 574 [76] Raya, R.; Garcia-Carmona, R.; Sanchez, C.; Urendes, E.; Ramirez, O.; Martin, A.; Otero, A. An  
575 Inexpensive and Easy to Use Cervical Range of Motion Measurement Solution Using Inertial  
576 Sensors. *Sensors*, **2018**, *18* (8), 2582. <https://doi.org/10.3390/s18082582>.
- 577 [77] Salem, W.; Klein, P. In Vivo 3D Kinematics of the Cervical Spine Segments during Pre-  
578 Manipulative Positioning at the C4/C5 Level. *Man. Ther.*, **2013**, *18* (4), 321–326.  
579 <https://doi.org/10.1016/j.math.2012.11.007>.
- 580 [78] Esteves, J. Predictive Processing and Allostatic Regulation in Clinical Practice. In *COME to*  
581 *Quantum Global: Allostasis the essence of clinical practice*; Catania (Italy), 2019; p 37.
- 582
- 583

584 **FIGURES legends**

585

586 **Figure 1.** Flowchart of the study.

587 **Figure 2.** Diagram and anatomical localization of markers used during the study; THD: Top

588 of head, FHD: Front of head, BHD: Back of head, FNS: Frontonasal suture, LTMJ: Left

589 temporomandibular joint, RTMJ: Right temporomandibular joint, RGA: Right Gonial Angle,

590 LGA: Left Gonial Angle, SIP: Superior incisive point, IIP: Inferior incisive point, RACJ:

591 Right acromio-clavicular joint, LACJ: Left acromio-clavicular joint, MP: Mental

592 protuberance, JN: Jugular notch, T1: First thoracic vertebra.

593 **Figure 3.** Experimental set up proposed and developed in this school-based protocol.

594 **Figure 4.** Jaw and cervical range of motion in the bruxism group before and after OMT or

595 sham treatment at one week before and after the second treatment session.

596

597

598

599

600

601

602

603

604

605



1 **Tables**

2

3 **Table 1:** Description of the Osteopathic Manipulative Treatment (OMT) and sham

## 4 interventions (TIDieR-Placebo checklist)

|  | OMT  | SHAM  |
|--|--|---|
| <b>WHY</b>                               | Provide usual osteopathic care expected to improve jaw and cervical mobility.  | Account for non-specific, contextual and natural effects and isolate the OMT component of the treatment.  |
| <b>PROCEDURES</b>                        | The session was personalized and included patient history taking (past experience, present state), physical examination, diagnostic osteopathic assessment, OMT, counselling, lifestyle change. Physical examination was done before and after treatment and included observation, global functional tests, pain provocation tests, orientation tests and local regional mobility assessment. Osteopaths were instructed to specifically evaluate jaw, cervical and upper thoracic motion. | The session was personalized and included patient history taking (past experience, present state), physical examination, diagnostic osteopathic assessment, and two sham procedures that mimicked OMT, counselling, lifestyle change. Physical examination was done before and after sham treatment and included observation, global functional tests, pain provocation tests, orientation tests and local regional mobility assessment. Osteopaths were instructed to specifically evaluate jaw, cervical and upper thoracic motion. |
| <b>WHO PROVIDED</b>                      | Participants were randomly allocated to receive treatment from one of six experienced osteopaths. All practitioners were educators with supervision experience within the school clinic. They had at least 10 years of experience in practice. All osteopaths received the same training for the procedures. There was no calibration on patient management.   |   |
| <b>HOW</b>                               | OMT was personalized for the patient by combining a wide range of osteopathic techniques “as usual” without receiving any instructions on decision criteria. Patient preferences were accounted for. OMT included soft tissue, MET and articulatory techniques, visceral and cranial techniques. Level of patient participation was not standardised across treatments.  | Osteopaths performed a predefined OMT technique on a specific region without any intent to induce changes in tissue mobility. Sham treatments were administered at two occasions in a random order. The sham treatment was the same for all participants and consisted of:<br>(1) Palpation of cranial mobility / MET for an inferior glenohumeral / Tissue technique of the 4th Left rib.<br>(2) Palpation of lower thorax orifice mobility / Soft tissue technique of zygomatic bones / MET on the right 5th rib posterolateral.    |
| <b>WHERE</b>                             | School clinic  |   |
| <b>HOW MUCH</b>                          | Two treatment sessions (45’) separated by one week   |   |
| <b>TAILORING</b>                         | The intervention was adapted and tailored to each participant including anamnesis, tests and treatment. Fidelity to protocol was assessed by analysing the reported interpretation and actions of osteopaths.  | The sham procedure was of two types described above. Fidelity to protocol was assessed by analysing the reported interpretation and actions of osteopaths.  |
| <b>MEASURING THE SUCCESS OF BLINDING</b> | Fifteen days’ follow-up, participants were asked whether they believed they were in the active or sham group.  |   |

5  
6  
7**Table 2:** Characteristics of participants of this study at baseline. \* Student T-test

|                                  | Group with bruxism          |                              |              | Group without bruxism       |                              |              |
|----------------------------------|-----------------------------|------------------------------|--------------|-----------------------------|------------------------------|--------------|
|                                  | OMT<br>n (%)   mean<br>(SD) | Sham<br>n (%)   mean<br>(SD) | p-value<br>* | OMT<br>n (%)   mean<br>(SD) | Sham<br>n (%)   mean<br>(SD) | p-value<br>* |
| Population (N=46)                | 13                          | 10                           |              | 12                          | 11                           |              |
| Sex; female                      | 10 (76.9%)                  | 8 (80%)                      |              | 8 (66.7%)                   | 8 (72.7%)                    |              |
| Age (years)                      | 21.2 ( $\pm$ 2.0)           | 21.0 ( $\pm$ 1.6)            |              | 20.7 ( $\pm$ 2.5)           | 20.3 ( $\pm$ 1.8)            |              |
| Weight (Kg)                      | 65.8 ( $\pm$ 15.8)          | 65.7 ( $\pm$ 13.0)           |              | 63.4 ( $\pm$ 6.4)           | 62.9 ( $\pm$ 9.6)            |              |
| Height (cm)                      | 171.4 ( $\pm$ 9.8)          | 171.5 ( $\pm$ 7.8)           |              | 168.2 ( $\pm$ 8.6)          | 167.2 ( $\pm$ 9.5)           |              |
| <b>Promotions</b>                |                             |                              |              |                             |                              |              |
| 1st year student                 | 2 (15.4%)                   | 2 (20%)                      |              | 4 (33.3%)                   | 3 (27.3%)                    |              |
| 2nd year student                 | 2 (15.4%)                   | 4 (40%)                      |              | 1 (8.3%)                    | 3 (27.3%)                    |              |
| 3rd year student                 | 4 (30.8%)                   | 1 (10%)                      |              | 1 (8.3%)                    | 2 (18.2%)                    |              |
| 4th year student                 | 5 (38.5%)                   | 3 (30%)                      |              | 6 (50%)                     | 3 (27.3%)                    |              |
| <b>Bruxism characteristics</b>   |                             |                              |              |                             |                              |              |
| Bruxism start (past years)       | 6.9 ( $\pm$ 5.6)            | 4.8 ( $\pm$ 4.7)             |              |                             |                              |              |
| Static bruxism                   | 7 (53.8%)                   | 6 (60%)                      |              |                             |                              |              |
| Dynamic bruxism                  | 1 (7.7%)                    | 0 (0%)                       |              |                             |                              |              |
| Mixed bruxism                    | 5 (38.5%)                   | 4 (40%)                      |              |                             |                              |              |
| Daytime bruxism                  | 2 (15.4%)                   | 0 (0%)                       |              |                             |                              |              |
| Nocturnal bruxism                | 3 (23.1%)                   | 6 (60%)                      |              |                             |                              |              |
| D and N bruxism                  | 8 (61.5%)                   | 4 (40%)                      |              |                             |                              |              |
| <b>Dental Health</b>             |                             |                              |              |                             |                              |              |
| Wisdom tooth extraction          | 10 (76.9%)                  | 5 (50%)                      |              | 5 (41.7%)                   | 2 (18.2%)                    |              |
| Other dental extraction          | 0 (0%)                      | 4 (40%)                      |              | 1 (8.3%)                    | 1 (9.1%)                     |              |
| <b>Range of motion (degrees)</b> |                             |                              |              |                             |                              |              |
| Jaw lateral movement             | 21.9 (5.3)                  | 24.0 (5.6)                   | p=0.371      | 18.2 (3.9)                  | 21.4 (3.5)                   | p=0.052      |
| Jaw opening                      | 28.4 (4.5)                  | 30.3 (5.4)                   | p=0.379      | 31.4 (6.1)                  | 34.6 (7.2)                   | p=0.266      |
| Cervical side-bending            | 66.4 (8.0)                  | 74.1 (10.5)                  | p=0.059      | 75.2 (6.7)                  | 73.7 (10.2)                  | p=0.663      |
| Cervical rotation                | 120.5 (8.8)                 | 132.1 (11.5)                 | p=0.012      | 138.9 (14.6)                | 142.8 (17.8)                 | p=0.568      |

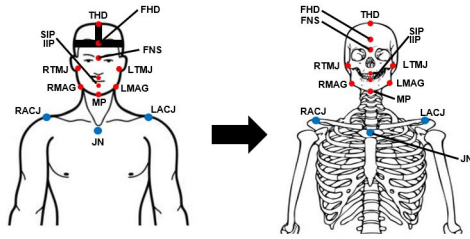
8  
9

10 **Table 3:** Gain in jaw and cervical range of motion range from baseline in the group with  
 11 bruxism at different time points. \* Between group difference adjusted for baseline value with  
 12 positive values representing increased range of motion for OMT group. † Primary outcome  
 13

|  | <b>OMT<br/>(n=13)<br/>mean (SD)</b> | <b>Sham<br/>(n=10)<br/>mean (SD)</b> | <b>Difference in changes from<br/>baseline*<br/>mean (CI95%; p-value)</b> |
|--|-------------------------------------|--------------------------------------|---|
| <b>Immediately after 1st session<br/>(D0)</b>            |                                     |                                      |   |
| Jaw lateral movement<br>(degrees)                        | 25.5° (4.0)                         | 23.6° (5.4)                          | 3.4° (1.0 to 5.8; p=0.007)  |
| Jaw opening (degrees)                                    | 30.1° (4.7)                         | 30.6° (5.7)                          | 1.3° (-0.7 to 3.3; p=0.201)   |
| Cervical side-bending<br>(degrees)                       | 72.9° (9.5)                         | 73.9° (8.2)                          | 5.2° (0.1 to 10.2; p=0.045)   |
| Cervical rotation<br>(degrees)                           | 128.2°<br>(11.5)                    | 133.0°<br>(11.4)                     | 7.8° (4.1 to 11.5; p<0.001)   |
| <b>Seven days after 1st session<br/>(D7)<sup>†</sup></b> |                                     |                                      |   |
| Jaw lateral movement<br>(degrees)                        | 25.9° (4.2)                         | 24.1° (5.6)                          | 3.3° (0.6 to 5.9; p=0.018)  |
| Jaw opening (degrees)                                    | 31.8° (5.6)                         | 31.0 (6.0)                           | 2.7° (-0.02 to 5.5; p=0.052)  |
| Cervical side-bending<br>(degrees)                       | 74.7 (11.1)                         | 76.6 (11.8)                          | 3.2° (-0.8 to 12.5; p=0.080)  |
| Cervical rotation<br>(degrees)                           | 134.7<br>(13.5)                     | 135.5<br>(12.5)                      | 12.0° (4.7 to 19.3; p=0.003)  |
| <b>Immediately after 2nd session<br/>(D7)</b>            |                                     |                                      |   |
| Jaw lateral movement<br>(degrees)                        | 27.5° (4.4)                         | 24.3° (6.3)                          | 4.8° (1.7 to 8.0; p=0.005)  |
| Jaw opening (degrees)                                    | 34.5° (5.6)                         | 30.8° (6.3)                          | 5.5° (2.2 to 8.7; p=0.002)  |
| Cervical side-bending<br>(degrees)                       | 76.9°<br>(12.5)                     | 75.1°<br>(11.0)                      | 9.2° (1.4 to 17.0; p=0.023)   |
| Cervical rotation<br>(degrees)                           | 139.6°<br>(14.7)                    | 135.9°<br>(15.1)                     | 18.2° (9.8 to 26.6; p<0.001)  |

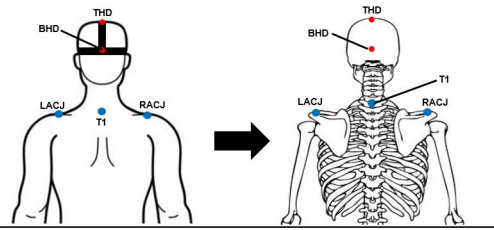
論

Journal Pre-proof



REAL PLACEMENT

ANATOMICAL TRANSPOSITION

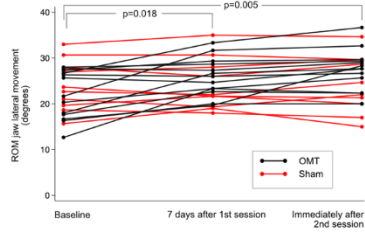


Journal Pre-proof

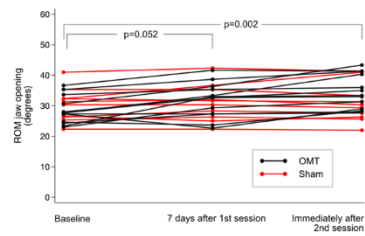


Journal Pre-proof

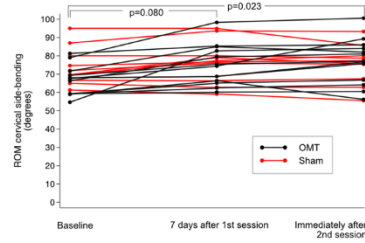
## A. Jaw lateral movement



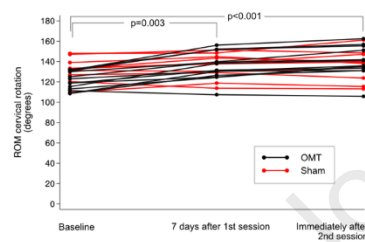
## B. Jaw opening



## C. Cervical side-bending



## C. Cervical rotation



**CONFLICT OF INTEREST FILE**

**(1) Conflict of Interest** – none

**(2) Funding Sources**

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Research staff were institution employees and a Master student. All costs related to the study were covered by the “Institut d’Ostéopathie de Rennes – Bretagne” except for the time spent by PV for statistical analysis and helping with writing the manuscript which were financed by the HES University of Applied Sciences and Arts Western Switzerland. Volunteers were not remunerated for their participations. The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript. The authors declare that they have no conflicts of interest.

**(3) Ethical approval details (if applicable)** - not applicable

**(4) Acknowledgments**

We acknowledge thank all students for their enthusiastic participation. We gratefully acknowledge Franck Sutre (DO), Florence Delauriere (DO, MSc), Alexis Guery (DO), Ludovic Lancelot (DO) and François Launay (DO) for their contribution to this study. The author also acknowledges Marylène Bourgin (DO, MM) and Emmanuel Harel (MM) for their logistic support during the two sessions of experimentation.