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Relationship among Cervical Spine Degeneration, Head and Neck postures, and Myofascial Pain in Masticatory and Cervical Muscles in Elderly with Temporomandibular Disorder

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ABSTRACT

Objectives: The aim of the study was to verify associations among degenerative changes in the cervical spine, head and neck postures, and myofascial pain in the craniocervical musculature in elderly with myofascial temporomandibular disorders (TMDs).

Methods: A total of 120 participants (mean age, 68.3 ± 7.5 years) were included: 45 participants had no signs of orofacial or cervical pain, 26 participants had myofascial TMD only (mTMD), and 49 participants had both myofascial TMD and cervical pain (cerTMD). Participants were diagnosed according to the Research Diagnostic Criteria for Temporomandibular Disorders. Cervical spine degeneration and head and neck postures were identified using the lateral cephalogram. Myofascial trigger points (TrPs) were evaluated in the temporalis, masseter, trapezius, sternocleidomastoid, sub-occipitalis, and splenius capitis muscles. Relationships among number of TrPs, head postures, and cervical degeneration were investigated using repeated-measure analysis of variance and Pearson's correlation coefficient.

Results: The cerTMD showed higher number of active TrPs in the masticatory and cervical muscles, greater forward head posture, and more severe degenerative changes in the cervical spine than mTMD did. The degenerative changes in each level of the cervical spine had complex interactions with head postures. Cervical degeneration, particularly at level of second to third vertebra appeared to be linked to the development of active TrPs in the masticatory and cervical muscles.

Conclusions: The results of this study demonstrated that degenerative changes in the cervical spine were related to altered head postures and the development of active TrPs in the craniocervical musculature in elderly with myofascial TMD.

1. Introduction

Temporomandibular disorders (TMDs) are described as a collection of conditions that affect the temporomandibular joints (TMJs) and masticatory muscles, along with the surrounding structures (de Leeuw & Klasser, 2013). The etiology of TMD is multifactorial in that no single contributing factor or unique model can explain its development (de Leeuw & Klasser, 2013). Among the diverse etiological factors, disorders in TMJ associated structures such as the cervical spine could affect the incidence of TMD and vice versa. Coexisting TMD and cervical spine disorders and their shared pathophysiological mechanisms have been previously reported (Bogduk, 1992; da Costa et al., 2015; de Santana, de Santana-Filho, Quintans-Junior, de Lima Ferreira, & Bonjardim, 2010; Fernandez-de-Las-Penas et al., 2010; Flores, Ottone, & Fuentes, 2017; Grondin, Hall, Laurentjoye, & Ella, 2015; Pallegama, Ranasinghe, Weerasinghe, & Sitheeque, 2004; Silveira, Armijo-Olivo, Gadotti, & Magee, 2014; Sonnesen, Bakke, & Solow, 2001).

Strong associations exist between the masticatory and cervical systems owing to their neurological and biomechanical interactions. The increased pain sensitivity of the cervical muscles in TMD patients and the decreased pain threshold of the masticatory muscles in patients with chronic neck pain have been observed (da Costa et al., 2015; Fernandez-de-Las-Penas et al., 2010; La Touche et al., 2010, 2015; Silveira et al., 2014). Furthermore, cervical spine mobilization could

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affect pain sensitivity in the masticatory muscles (La Touche et al., 2009, 2013). The cranium, mandible, and cervical spine form a functional unit called the "craniocervical-mandibular system" and this biomechanical interplay may be involved in functional dependence between the cervical and masticatory systems. The range of motion of the neck and the activities of the cervical muscles appeared to be altered in TMD patients and changes in head and neck position could influence the activities of the masticatory muscles and jaw function (Armijo-Olivo et al., 2011; Eriksson, Haggman-Henrikson, Nordh, & Zafar, 2000; Grondin et al., 2015; La Touche et al., 2011; Pallegama et al., 2004). Therefore, an integrated approach that include both the masticatory and cervical systems is necessary for the proper management of cervical spine disorders as a comorbity of TMD.

Head and neck posture is an indicator of the biomechanical equilibrium of the cranium and upper cervical spine. The factors involved in controlling head and neck posture include proprioceptors of the neck, neuromuscular activity, vertebral morphology, and degenerative changes of the facet joint (Boucher, Descarreaux, & Normand, 2008; de Farias Neto et al., 2010; Fernandez-de-Las-Penas et al., 2010; Flores et al., 2017; La Touche et al., 2010). Forward head posture (FHP) seemed to be associated with decreased pain threshold and the development of active trigger points (TrPs) in the cervical and masticatory muscles. Myofascial pain (MFP) in the cervical muscles may also cause antalgic FHP to reduce pain by shortening the vertical extensor muscles (de Farias Neto et al., 2010; Fernandez-de-Las-Penas, Cuadrado, & Pareja, 2007, 2010; Sonnesen et al., 2001).

Aging could accompany degenerative changes in the spinal structures, including the vertebral body, facet areas, and intervertebral discs. Disc degeneration in the cervical spine is common in individuals aged over 50 years, and is generally considered part of the normal aging process (Christian, 1992). It may be related to intervertebral disc space narrowing, loss of neck range of motion, reduced masticatory and cervical muscle strength, and postural instability (Boucher et al., 2008; Christian, 1992; Dunlop, Adams, & Hutton, 1984; Gore, Sepic, & Gardner, 1986). Thus, one hypothes is that degenerative changes in the upper cervical spine are associated with head and neck postures and MFP in the masticatory and cervical muscles could be derived. However, sparse studies have ever attempted to reveal the relationships among them. Therefore, the purpose of the present study was to verify the associations among degenerative changes in the upper cervical spine, head and neck postures, and MFP in the craniocervical musculature in elderly TMD patients.

2. Methods

2.1. Participants

This was a cross sectional study using the clinical and radiographic records of 120 (53 male, 67 female; mean age 68.3 ± 7.5 years; age range 60–98 years) elderly who visited the TMJ·Orofacial Pain Clinic at a tertiary medical center from March 2017 to June 2018. Participants with the following conditions were excluded: autoimmune diseases, such as rheumatoid arthritis, systemic lupus erythematosus, and fibromyalgia; craniofacial anomalies; history of head and neck trauma; neuromuscular disorders; chronic fatigue syndrome; wearing removable dentures; loss of posterior teeth; and communication incapability.

The participants were classified into three groups according to the presence of myofascial TMD and self-reported cervical pain. The participants in the normal control group comprised 45 individuals who visited the clinic for dental and TMJ check-ups and had no orofacial or cervical discomfort in the last six months (CON). For experimental groups, 26 participants with myofascial TMD only (mTMD) and 49 participants with both myofascial TMD and self-reported cervical pain (cerTMD) were included. Orofacial pain duration in the experimental groups lasted more than six months. Participants were diagnosed according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) Axis I (Dworkin & LeResche, 1992).

The research protocol was approved by the Institutional Review Board of the University Hospital (AJIRB-MED-MDB-18-191).

2.2. Diagnosis of TMD and evaluation of active trigger points

The RDC/TMD Axis I criteria was used to classify myofascial TMD. A single TMD and orofacial pain specialist (JHK) was responsible for assessing TMD and TrPs. Clinical parameters such as amounts of comfortable mouth opening (CMO) without pain and maximum mouth opening (MMO), and duration of TMD symptoms were analyzed. CMO and MMO measurements were made from the incisal border of the central upper incisor to the same point on the lower incisor. The visual analog scale (VAS) and graded chronic pain severity (GCPS) according to the RDC/TMD axis II were applied to assess the severity of chronic pain. Myofascial TrPs were bilaterally evaluated in the temporalis, masseter, trapezius, sternocleidomastoid, sub-occipitalis, and splenius capitis muscles. TrPs were evaluated on the basis of the criteria suggested by Simon (Simon, Travell, & Simon, 1999): presence of a palpable taut band in the muscles; presence of a hypersensitive spot in the taut band; local twitch response on palpation of the taut band; and reproduction of referred pain in response to palpation. TrPs were considered being active if the referred pain occurred and was recognized by patients as their usual pain. Otherwise TrPs were regarded latent when the referred pain did not occurred. The data from the cephalometric analysis were blinded to the examiner during examination.

2.3. Diagnosis of degenerative changes in the cervical spine

An orthopedic surgeon (SWH) identified cervical disc degeneration and the presence of osteophytes. The grading system covered three major radiographic changes of the cervical spine: "height loss", "osteophyte formation", and "diffuse sclerosis" (Kettler et al., 2006). "Total degeneration" was obtained for each intervertebral space on the basis of the sum of the three scores. The validity and reliability of the grading system was previously confirmed (Kettler et al., 2006).

"Height loss" was defined as the average anterior and posterior decrease in disc height compared to the respective height before degeneration. The respective individual disc height before degeneration was estimated by the normal values suggested by Frobin and this normal values exhibit a dependence on gender, not on age (Frobin, Leivseth, Biggemann, & Brinckmann, 2002). For assessment, the actual anterior and posterior disc height were determined. The distance of each of the four edges to the mid-plane of the disc was measured. The sum of the two anterior or two posterior disc heights was defined as the actual anterior or posterior disc height, respectively (Fig. 1A). "Height loss" was graded as follows: 0 for no change, 1 for ≤ 33% change, 2 for ≥ 33% but < 66% change, and 3 for ≥ 66% change.

"Osteophyte formation" was determined as the sum of points assessed by the length of the osteophyte at the four edges. The length of the osteophyte was measured along the long axis from the border of the vertebral body to its tips (Fig. 1B). The point system was as follows: 0 points for no osteophyte, 1 point for ≤ 2 mm length, 2 points for ≥ 2 mm but < 4 mm length, and 3 points for ≥ 4 mm length. "Osteophyte formation" was graded as follows: 0 for 0 points, 1 for 1–4 points, 2 for 5–8 points, and 3 for 9–12 points.

"Diffuse sclerosis" was estimated as the sum of the points of both adjacent vertebral bodies. The lower half of the upper vertebral body (C1, C2) and the upper half of the lower vertebral body (D1, D2) were divided into two regions. Those regions covered by sclerosis were counted in the case of diffuse borders and the thickened bony endplate (Fig. 1C). The point system used was as follows: 0 points for no sclerosis, 1 point for less than half affected, and 2 points for more than half or completely affected. The grading system of "diffuse sclerosis" indicated 0 for 0 points, 1 for 1 point, 2 for 2 points, and 3 for 3–4 points.

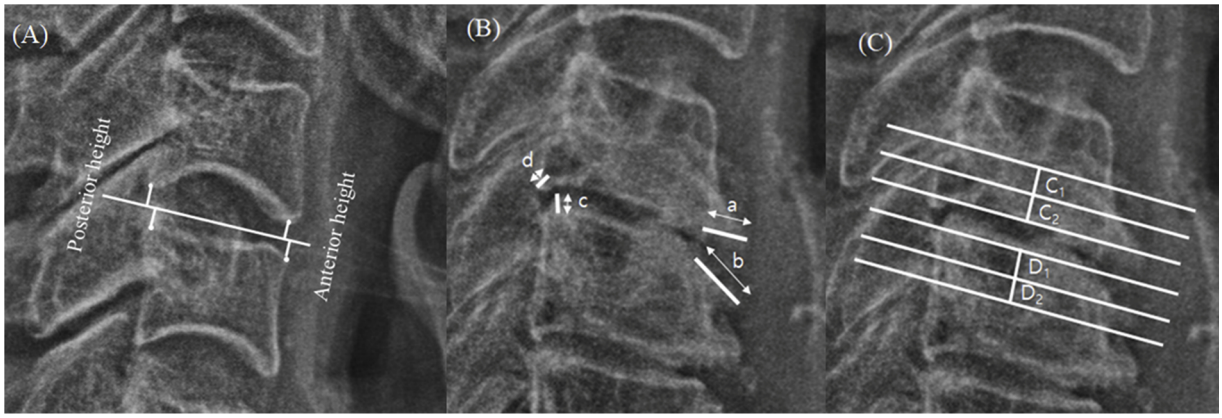

Fig. 1. (A) "Height loss" was defined as the average anterior and posterior decrease in the disc height compared to the respective height before degeneration. The sum of the two anterior or two posterior disc height was defined as actual anterior or posterior disc height, respectively. (B) "Osteophyte formation" was determined as the sum of points assessed by the length of osteophyte of four edges. The length of the osteophyte was measured along the long axis from the border of the vertebral body to its tips. (C) "Diffuse sclerosis" was estimated as the sum of points of both adjacent vertebral bodies. The lower half of the upper vertebral body (C1, C2) and upper half of the lower vertebral body (D1, D2) were divided into two regions.

"Total degeneration" was defined as the sum of the grades of "height loss", "osteophyte formation", and "diffuse sclerosis". The grading system was as follows: grade 0 for 0 points (no degeneration), 1 (mild degeneration) for 1–3 points, 2 (moderate degeneration) for 4–6 points, and 3 (severe degeneration) for 7–9 points.

Determination of degree of cervical degeneration was performed independently by two observers including one orthopedic surgeon (SWH) and one radiologist. Cohen's kappa test was used to assess the reliability and the coefficient was 0.705, suggesting good agreement. One observer (SWH) repeated the process after 1 week (intra-examiner) and data were compared using intraclass correlation coefficient (ICC) and acceptable agreement was observed. Each examiner was blinded to the other and clinical information was blinded to each examiner also.

2.4. Appraisal of head and neck posture

One TMD and orofacial pain specialist (JHK) analyzed head and neck posture via cephalometric analysis using V-ceph® 5.0 software (Cybermed, Seoul, Korea) (Rocabado, 1983; Solow & Tallgren, 1976) (Fig. 2). To assess inter-examiner reliability, one orofacial pain and TMD specialist (JHK) and one radiologist evaluated 20 randomly selected cephalometric radiographs and data from each examiner was compared using ICC to assess the reliability. Each examiner was blinded to the other and clinical information was also blinded to each examiner. The ICC was 0.643, suggesting substantial agreement. One observer (JHK) repeated the process after 2 weeks (intra-examiner) and data were compared using ICC and acceptable agreement was observed.

- OPT – CVT: the angulation of the OPT (posterior tangent to the odontoid process through the inferior - posterior point of the second vertebra [C2ip]) and CVT (posterior tangent to the odontoid process through the inferior - posterior point of the fourth vertebra [C4ip])
- Ba – C3ia: the distance between basion (Ba) and the most inferior-anterior point on the body of the third vertebra (C3ia)
- Cranium-atlas distance (C0 – 1): the distance between the base of the occiput (C0) and the posterior arch of the atlas (C1)
- Atlas-axis distance (C1 – 2): the distance between the posterior arch of the atlas (C1) and the spinous process of the second vertebra (C2)
- Hyoid triangle height: the height of the triangle made by three points, namely, the most superior–anterior point of the hyoid (H), the inferior and anterior point of the third vertebra (C3ia), and retrognathion (RGN).

2.5. Statistical evaluation

The normality of data was affirmed using the Kolmogorov-Smirnov normality test to adopt parametric statistical testing. To compare the differences in demographic features, clinical parameters, head and neck posture, and severity of degenerative changes of the cervical spine among the groups, one-way analysis of variance (ANOVA) followed by post hoc analysis with Bonferroni's test and Chi-square test were applied for continuous and categorical variables, respectively. The relationships between cervical degeneration, head and neck postures, and number of TrPs in the masticatory and cervical muscles were determined using three-way repeated measure ANOVA. The associations among head posture, number of active and latent TrPs in the masticatory and cervical muscles were estimated using Pearson's correlation coefficient. All tests were two-sided and *P*-values less than 0.05 were considered statistically significant.

3. Results

3.1. Demographic features and clinical evaluation

Age ($P = 0.164$) and sex distribution ($P = 0.941$) were not significantly different among the groups. The longer duration of TMD symptoms ($P = 0.001$) and decreased amount of CMO ($P = 0.016$) and MMO ($P = 0.021$) were observed in the cerTMD than those in the mTMD, but between-group significances were not reached. TMD pain intensity was higher in the cerTMD (VAS = 6.78 ± 2.75) than in the mTMD (VAS = 5.12 ± 2.47) without between-group significance ($P < 0.001$). The number of active TrPs in cerTMD was obviously greater than those in mTMD and CON but the number of latent TrPs in those muscles was not. The cerTMD showed significantly higher number of active TrPs in the masticatory ($P < 0.001$) and cervical muscles ($P < 0.001$) and a higher number of latent TrPs in the cervical muscles ($P < 0.001$) than the mTMD did. The number of active TrPs in both temporalis muscles and masseter muscles was significantly higher in cerTMD than in mTMD but the number of active TrPs in cervical muscles did not show significant differences between mTMD and cerTMD except trapezius muscles (data none shown). GCPS was significantly higher in the cerTMD than that in the mTMD and CON ($P < 0.001$) (Table 1).

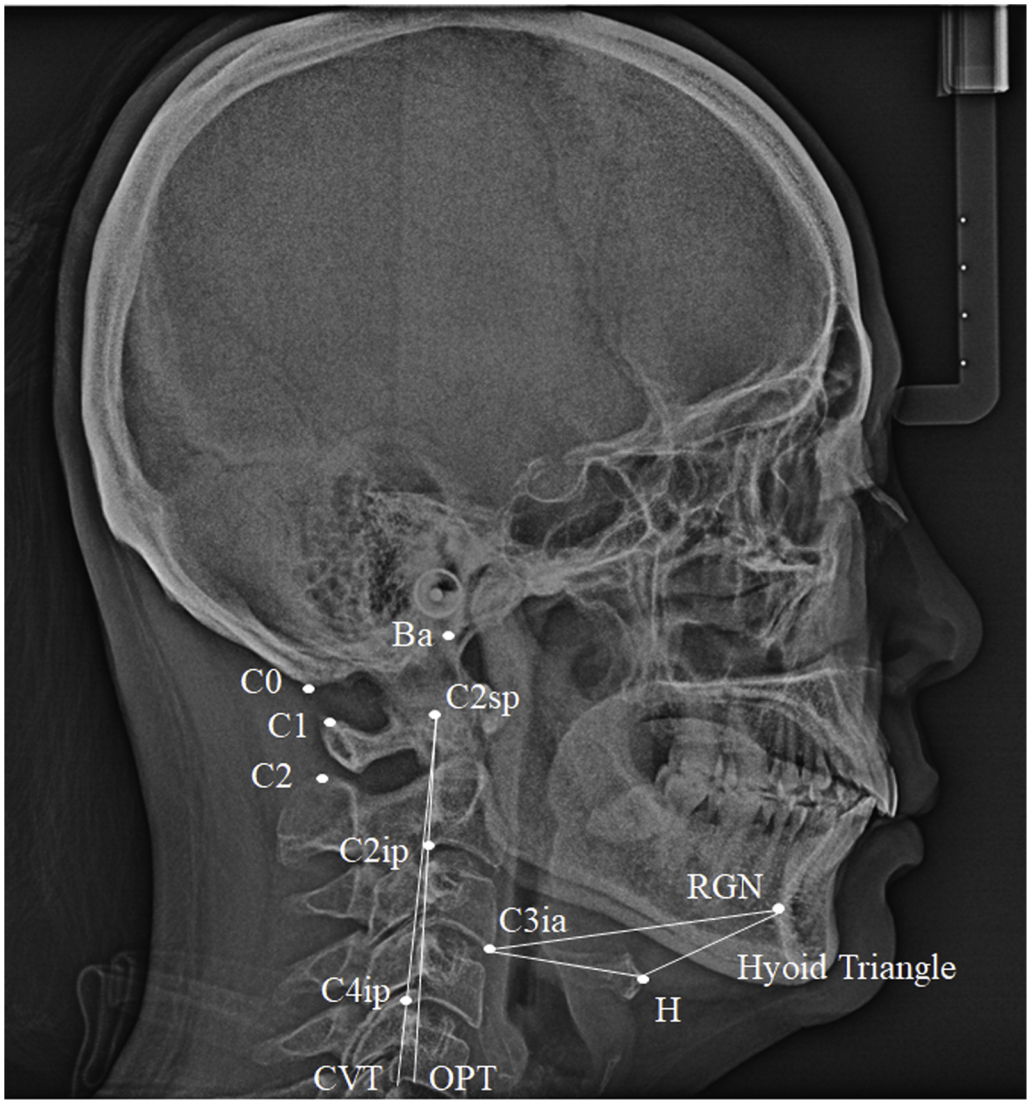

Fig. 2. Cephalometric landmarks and variables used in the study.
Ba, basion; H, the most superior-anterior point of the hyoid; RGN, retrognathion; C0. Base of the occiput; C1, the posterior arch of the atlas; C2, the spinous process of the second vertebra; C2sp, the most superior-posterior point on the body of the second vertebra; C2ip, the most inferior-posterior point on the body of the second vertebra; C3ia, the most inferior-anterior point on the body of the third vertebra; C4ip, the most inferior-posterior point on the body of the fourth vertebra; OPT, posterior tangent to the odontoid process through C2ip; CVT, posterior tangent to the odontoid process through inferior C4ip; hyoid triangle, the triangle made by three points, H, C3ia, and RGN

3.2. Head and neck postures and severity of degeneration in the upper cervical spine

Participants in the cerTMD appeared to have more severe FHP than those in the mTMD and CON did. Larger values of OPT-CVT and Ba-C3ai represent more FHP and smaller distance of C0 – 1 means posterior rotation of cranium. OPT - CVT was the largest in the cerTMD followed by that in the mTMD and CON in terns ($P < 0.001$). Decreased intervertebral spaces were observed in mTMD and cerTMD. C0 – 1 ($P = 0.019$) and C1 – 2 ($P < 0.001$) were the lowest in cerTMD followed by mTMD and CON, but between-group significances of the cerTMD and mTMD were not reached (Table 2).

The degree of degenerative changes in the cervical spine showed significant differences. Degree of total degeneration at the levels of C2 to C3 ($P < 0.001$), C3 to C4 ($P = 0.048$), and C4 to C5 ($P < 0.001$) were significantly different among the groups (Table 2).

3.3. Relationships between severity of cervical disc degeneration and head and neck posture

The degenerative changes of the cervical spine appeared to be associated with FHP. OPT - CVT was significantly influenced by degenerative changes at the level of C2 to C3 ($P = 0.020$). When the degree of degeneration at the level of C3 to C4 and that of C4 to C5 were considered, OPT - CVT still showed statistical significance ($P = 0.049$). The C0 – C1 did not appear to have relevance with degenerations at the level of C2 to C3 ($P = 0.424$), C3 to C4 ($P = 0.187$), and C4 to C5 ($P = 0.706$) each, but their total interaction had significant associations ($P = 0.017$). Otherwise, C1 – C2 was influenced by the interactions between degenerative changes at the level of C2 to C3 and those at the level of C3 to C4 ($P = 0.049$) and interactions between degeneration at the levels of C3 to C4 and those at the level of C4 to C5 ($P = 0.012$). However, their total interactions did not have a significant influence on C1 – C2 ($P = 0.214$) (Table 3).

3.4. Relationships between the severity of cervical disc degeneration and number of TrPs in masticatory and cervical muscles

The degenerative changes at the level of C2 to C3 showed significant associations with the number of active TrPs of both masticatory ($P = 0.005$) and cervical muscles ($P = 0.009$). On the other hand, the influences of degeneration in the cervical spine at each intervertebral level on the number of latent TrPs in masticatory and cervical muscles were not significant. When the interactions between the degenerations at the level of C2 to C3 and those at the level of C3 to C4 were considered, the statistically significant relationships appeared in the number of latent TrPs in the masticatory muscles ($P = 0.001$) (Table 4).

Table 1
Demographic features and clinical parameters in three groups.

	CON (n = 45)	mTMD (n = 26)	cerTMD (n = 49)	*P* value	Post-hoc
Age (years)	66.9 ± 7.5	70.4 ± 8.4	68.6 ± 6.7	0.164	–
Sex (male/female)[a]	19/26	12/14	22/27	0.941	–
BMI	23.4 ± 4.2	22.6 ± 1.8	26.0 ± 22.1	0.557	–
TMD symptom duration (months)	0	14.7 ± 19.6	27.3 ± 36.5	< 0.001**	CON-cerTMD
CMO (mm)	45.0 ± 5.9	44.2 ± 7.2	41.0 ± 7.4	0.016*	CON-cerTMD
MMO (mm)	45.3 ± 5.1	45.7 ± 6.6	42.8 ± 6.8	0.021*	CON-cerTMD
VAS from TMD	0	5.12 ± 2.47	6.78 ± 2.75	< 0.001**	CON-mTMD, CON-cerTMD
Number of active trigger points in masticatory muscles	0	1.65 ± 1.32	2.47 ± 1.60	< 0.001**	CON-mTMD, CON-cerTMD, mTMD-cerTMD
Number of active trigger points in cervical muscles	0	1.15 ± 1.76	5.10 ± 3.18	< 0.001**	CON-cerTMD, mTMD-cerTMD
Number of latent trigger points in masticatory muscles	0	0.62 ± 0.85	0.71 ± 1.15	0.096	–
Number of latent trigger points in cervical muscles	0	0.04 ± 0.30	1.04 ± 1.93	< 0.001**	CON-cerTMD, mTMD-cerTMD
GCPS†	0	2 (1 – 1)	3 (1 – 1)	< 0.001**	–

TMD, temporomandibular disorder; BMI, body mass index; CON, participants showing no signs of myofascial TMD or cervical pain; mTMD, participants with myofascial TMD; cerTMD, participants with both myofascial TMD and cervical pain; CMO, comfortable mouth opening; MMO, maximum mouth opening; VAS, visual analog scale; GCPS, graded chronic pain scale.
Descriptive values are shown as mean ± SD or median (25th – 75th percentile).
Data obtained from one-way ANOVA with Bonferroni's post-hoc analysis.
[a] Data obtained from Chi-square test.
* $P < 0.05$.
** $P < 0.001$ by one-way ANOVA with Bonferroni's post-hoc analysis and Chi square test.

3.5. Correlations between the head and neck postures and the number of TrPs in masticatory and cervical muscles

The number of active TrPs in both masticatory and cervical muscles was significantly associated with FHP. The number of active TrPs was significantly correlated with OPT - CVT (r = 0.510, $P < 0.001$)) and Ba – C3ai (r = 0.311, $P < 0.001$), C0 – C1 (r = -0.218, $P = 0.017$) and C1 – C2 (r = −0.360, $P < 0.001$). The number of active TrPs in the cervical muscles significantly corresponded with OPT - CVT (r = 0.602, $P < 0.001$), C0 – C1 (r = -0.268, $P = 0.003$) and the C1 – C2 (r = −0.272, $P = 0.003$). However, the number of latent TrPs in both masticatory and cervical muscles was not significantly associated with head and neck postures (Table 5).

4. Discussion

Degenerative changes in the cervical spine are considered part of the normal aging process. Disc degeneration was associated with less cervical lordosis and altered vertebral alignment, which could induce abnormal load distribution via the facet joints to the surrounding musculature (Dunlop et al., 1984; Gore et al., 1986). Previous studies have attempted to determine the relationships between MFP sensitization process in the masticatory muscles and altered craniocervical postures (de Farias Neto et al., 2010; La Touche et al., 2011; Sonnesen et al., 2001). The FHP seemed to have associations with both upper cervical degeneration and MFP sensitization procedures in craniocervical system. However, sparse studies have investigated the

Table 2
Head and neck postures and severity of degeneration of the cervical spine.

	CON (n = 45)	mTMD (n = 26)	cerTMD (n = 49)	*P* value	Post-hoc
OPT-CVT	13.7 ± 1.7	14.6 ± 2.9	17.4 ± 4.7	< 0.001**	CON-cerTMD, mTMD-cerTMD
Ba-C3ia	174.5 ± 18.2	180.2 ± 30.5	181.0 ± 28.1	0.518	–
C0-1	26.3 ± 8.3	25.8 ± 8.4	22.3 ± 6.6	0.019*	CON-cerTMD
C1-2	39.6 ± 8.9	32.9 ± 8.1	31.3 ± 9.9	< 0.001**	CON-mTMD, CON-cerTMD
Hyoid triangle	11.4 ± 34.7	−3.70 ± 34.74	7.45 ± 38.56	0.213	–
C2 to C3 Total grade[a]	2 (1 – 1)	2 (1 – 1)	2 (1 – 1)	< 0.001**	–
C3 to C4 Total grade[a]	2 (1 – 1)	2 (1 – 1)	2 (1 – 1)	0.048*	–
C4 to C5 Total grade[a]	2 (1 – 1)	3 (1 – 1)	3 (1 – 1)	< 0.001**	–

CON, participants showing no signs of myofascial or arthralgia TMD; mTMD, participants with myofascial TMD; cerTMD, participants with both myofascial TMD and cervical pain; OPT, posterior tangent to the odontoid process through inferior posterior point of C2; CVT, posterior tangent to the odontoid process through inferior posterior point of C4; Ba-C3ia, the distance between basion (Ba) and the most inferior-anterior point on the body of the third vertebra (C3ia) ; C0-1, the distance between base of the occiput and the posterior arch of the atlas; C1-2, the distance between the posterior arch of the atlas and the spinous process of the second vertebra; hyoid triangle, the height of the triangle made by three points, the most superior and anterior point of the hyoid (H), the inferior and anterior point of the third vertebra (C3ia), and retrognathion (RGN); C2, the second vertebra; C3, the third vertebra; C4, the forth vertebra; C5, the fifth vertebra.
Descriptive values are shown as mean ± SD or median (25^{th} – 75^{th} percentile).
Data obtained from one-way ANOVA with Bonferroni's post-hoc analysis.
[a] Data obtained from Chi-square test.
* $P < 0.05$.
** $P < 0.001$ by one-way ANOVA with Bonferroni's post-hoc analysis and Chi square test.

Table 3
Associations between severity of the cervical degeneration and the head and neck postures.

Head and neck postures	Total degeneration level					*P* value						
	C2 to C3	C3 to C4	C4 to C5									
			C4-5 mild	C4-5 moderate	C4-5 severe	C2-3	C3-4	C4-5	C2-3 * C3-4	C2-3 * C4-5	C3-4 * C4-5	C2-3 * C3-4 * C4-5
OPT-CVT	C2-3	C3-4 mild	11.0 ± 0.1	12.5 ± 0.7	12.6 ± 0.1	0.020*	0.488	0.255	0.136	0.172	0.778	0.049*
	mild	C3-4 moderate	12.8 ± 0.4	12.5 ± 1.7	14.2 ± 0.2							
		C3-4 severe	12.4 ± 2.1	11.9 ± 0.7	14.7 ± 0.7							
	C2-3 moderate	C3-4 mild	14.4 ± 1.7	14.0 ± 2.5	15.8 ± 2.3							
		C3-4 moderate	13.1 ± 1.6	14.2 ± 2.9	17.7 ± 3.6							
		C3-4 severe	15.5 ± 0.7	13.3 ± 0.8	20.3 ± 4.3							
	C2-3	C3-4 mild	25.0 ± 0.1	25.5 ± 2.1	20.6 ± 9.8							
	severe	C3-4 moderate	23.8 ± 4.5	21.0 ± 1.9	21.4 ± 4.9							
		C3-4 severe	14.9 ± 0.9	28.1 ± 0.8	21.8 ± 4.8							
Ba-C3ia	C2-3	C3-4 mild	147.7 ± 0.4	155.3 ± 6.6	155.3 ± 0.4	0.134	0.317	0.642	0.048*	0.467	0.917	0.794
	mild	C3-4 moderate	157.8 ± 3.1	176.3 ± 20.1	169.2 ± 5.9							
		C3-4 severe	172.1 ± 11.8	188.0 ± 4.8	175.0 ± 33.4							
	C2-3 moderate	C3-4 mild	215.0 ± 37.0	217.0 ± 53.1	185.4 ± 36.7							
		C3-4 moderate	178.8 ± 22.9	175.5 ± 14.7	175.3 ± 22.3							
		C3-4 severe	169.0 ± 15.6	182.4 ± 17.7	177.3 ± 35.6							
	C2-3	C3-4 mild	125.0 ± 35.4	157.5 ± 10.6	161.5 ± 3.5							
	severe	C3-4 moderate	167.5 ± 17.7	135.5 ± 0.7	203.9 ± 29.9							
		C3-4 severe	179.3 ± 1.1	177.5 ± 3.5	181.5 ± 30.7							
C0-1	C2-3	C3-4 mild	23.1 ± 0.1	23.5 ± 0.7	22.9 ± 0.1	0.424	0.187	0.706	0.838	0.665	0.751	0.017*
	mild	C3-4 moderate	22.0 ± 0.1	25.6 ± 3.9	31.2 ± 1.7							
		C3-4 severe	22.4 ± 13.7	29.2 ± 3.4	15.3 ± 10.6							
	C2-3 moderate	C3-4 mild	30.4 ± 15.0	23.8 ± 10.3	17.6 ± 7.4							
		C3-4 moderate	27.0 ± 7.8	27.3 ± 6.8	23.2 ± 6.6							
		C3-4 severe	15.0 ± 7.1	16.4 ± 8.2	23.7 ± 8.6							
	C2-3	C3-4 mild	15.0 ± 0.1	14.5 ± 0.7	18.3 ± 5.1							
	severe	C3-4 moderate	26.2 ± 1.7	27.8 ± 0.4	17.0 ± 5.4							
		C3-4 severe	23.8 ± 0.2	16.1 ± 0.6	20.5 ± 7.9							
C1-2	C2-3	C3-4 mild	44.1 ± 0.1	37.5 ± 10.6	28.0 ± 0.1	0.504	0.805	0.717	0.271	0.049*	0.012*	0.214
	mild	C3-4 moderate	31.0 ± 1.4	40.5 ± 6.6	45.3 ± 0.5							
		C3-4 severe	33.5 ± 11.2	38.7 ± 7.0	37.4 ± 3.8							
	C2-3 moderate	C3-4 mild	22.1 ± 2.1	40.8 ± 6.3	32.8 ± 7.4							
		C3-4 moderate	38.7 ± 10.0	36.4 ± 9.2	30.1 ± 8.8							
		C3-4 severe	26.5 ± 2.1	48.0 ± 6.0	31.4 ± 9.8							
	C2-3	C3-4 mild	40.0 ± 0.1	40.0 ± 0.1	40.6 ± 1.3							
	severe	C3-4 moderate	33.8 ± 1.1	30.7 ± 8.4	25.9 ± 11.9							
		C3-4 severe	38.8 ± 4.7	23.7 ± 2.0	31.4 ± 12.0							

(*continued on next page*)

Table 3 (*continued*)

Head and neck postures	Total degeneration level					*P* value								
	C2 to C3	C3 to C4	C4 to C5											
			C4-5 mild	C4-5 moderate	C4-5 severe	C2-3	C3-4	C4-5	C2-3 * C3-4	C2-3 * C4-5	C3-4 * C4-5	C2-3 * C3-4 * C4-5		
Hyoid triangle	C2-3 mild	C3-4 mild	−16.0 ± 5.6	−26.0 ± 1.4	−36.0 ± 1.5	0.334	0.177	0.096	0.070	0.470	0.721	0.455		
		C3-4 moderate	−2.5 ± 38.9	−23.8 ± 15.5	−11.7 ± 6.1									
		C3-4 severe	4.70 ± 38.18	36.3 ± 6.7	16.0 ± 11.2									
	C2-3 moderate	C3-4 mild	−1.41 ± 83.44	−16.2 ± 1.4	0.15 ± 45.91									
		C3-4 moderate	17.6 ± 35.4	6.38 ± 32.15	−2.74 ± 31.15									
		C3-4 severe	12.5 ± 3.5	1.08 ± 20.1	7.90 ± 44.79									
	C2-3 severe	C3-4 mild	−15.0 ± 0.4	−14.0 ± 1.4	2.44 ± 22.24									
		C3-4 moderate	62.8 ± 18.0	−21.4 ± 12.9	19.0 ± 44.7									
		C3-4 severe	30.4 ± 34.9	40.0 ± 7.1	21.9 ± 52.6									

OPT, posterior tangent to the odontoid process through inferior posterior point of C2; CVT, posterior tangent to the odontoid process through inferior posterior point of C4; Ba-C3ia, the distance between basion (Ba) and the most inferior-anterior point on the body of the third vertebra (C3ia) ; C0-1, the distance between base of the occiput and the posterior arch of the atlas; C1-2, the distance between the posterior arch of the atlas and the spinous process of the second vertebra; hyoid triangle, the height of the triangle made by three points, the most superior and anterior point of the hyoid (H), the inferior and anterior point of the third vertebra (C3ia), and retrognathion (RGN); C2, the second vertebra; C3, the third vertebra; C4, the forth vertebra; C5, the fifth vertebra; *, interaction.
Descriptive values are shown as mean ± SD or median.
Data obtained from three-way repeated measure ANOVA.
** $P < 0.001$ by three-way repeated measure ANOVA.
* $P < 0.05$.

relationships among the degenerative changes of the cervical spine, head and neck postures, and MFP development in the masticatory and cervical muscles in elderly individuals.

Despite the lack of significant differences regarding TMD symptom duration and pain intensity between two groups, aforementioned results showed that participants with both cervical pain and myofascial TMD had more severe FHP and a higher number of active TrPs in the masticaotry and cervical muscles than those with only myofascial TMD did. The increased forward inclination of the upper cervical spine in TMD patients have been well reported (Flores et al., 2017; Sonnesen, Pedersen, & Kjaer, 2007). Excessive capsular ligament stretch beyond biophysical limitations from FHP could decrease the threshold of nerve endings and activate proprioceptors in facet joint capsules, which have a role in development of cervical muscle pain (Cavanaugh, Lu, Chen, & Kallakuri, 2006). Threfore, more severe FHP induced by increased levels of masticatory MFP may increase the chance of developing cervical pain by excessive capsular ligament stretching and abnormal load distribution.

Interestingly, the participants with both myofascial TMD and cervical pain showed more severe degenerative changes of the upper cervical spine. With increasing age, paraspinal muscle mass decreases, leading to the decreased stabilization of the vertebral column, which may accelerate the degenerative changes in the vertebral disc (Kalichman, Hodges, Li, Guermazi, & Hunter, 2010). Degenerative changes tend to produce less cervical lordosis and altered vertebral alignment, which may induce abnormal force transmission across the facet joints and surrounding musculature (Dunlop et al., 1984; Gore et al., 1986). The painful middle and lower cervical facet joints can cause pain in the posterior scapular region, with some pain radiation around the shoulder girdle (Aprill, Dwyer, & Bogduk, 1990; Dwyer, Aprill, & Bogduk, 1990). Furthermore, the synovial fold, which contains substance P and calcitonin gene-related peptide, may become damaged owing to cervical facet compression, thus causing mechanical hyperalgesia (Lee & Winkelstein, 2009). Therefore, degenerative vertebral compression could lead to the accumulation of inflammatory neurotransmitters in the cervical muscles, which may have relavance with active TrP in the cervical muscles. Furthermore, several reports carefully suggested that FHP might be a consequence of cervical and neck pain because individuals with cervical and neck pain try to shorten the vertical extensor muscles including the sub-occipital, splinius capitis, trapezius, and sternocleidomastoid muscles, to reduce pain (de Farias Neto et al., 2010; Fernandez-de-Las-Penas et al., 2007, 2010; Sonnesen et al., 2001). Hence, degeneration of the upper cervical spine may be related to the MFP sensitization process in the cervical muscles, and cervical myofacial pain could also be associated with FHP and vice versa.

The novel findings of the present study included the relationships between the degenerative changes of the upper cervical spine and the number of active TrPs in the masticatory muscles. Degeneration, particularly at the level of C2 to C3 showed significant relevance with the number of active TrPs in the masticatory and cervical muscles, respectively. Previous studies suggested widespread pain distribution in TMD patients and significant overlap between orofacial pain and pain conditions in outside of the face, particularly the shoulder and neck (Hagberg, 1991; Turp, Kowalski, O'Leary, & Stohler, 1998). Furthermore, an animal study demonstrated a neuronal link between motor trigeminal nucleus, subnucleus oralis neurons, and cervical axons from C2 and C3 segments (Xiong & Matsushita, 2000). Degeneration in the upper cervical spine, particulary in the C2 to C3 area may elicit deep cervical pain owing to inflammatory cytokines accumulation and altered vertical alignment. This type of deep cervical muscle pain may have a role in the occurrence of referred pain in the masticatory muscles (Okeson, 2013). Previous report suggested that the activities of the masseter muscle might increase when facial pain was experimentally induced in normal subjects (Stohler, Yamada, & Ash, 1985). Therefore, sustained referred pain in the orofacial area from primary cervical MFP

Table 4
Associations between severity of the cervical degeneration and number of TrPs in the masticatory and cervical muscles.

Number of TrPs		Total degeneration level					*P* value						
		C2 to C3	C3 to C4	C4 to C5									
				C4-5 mild	C4-5 moderate	C4-5 severe	C2-3	C3-4	C4-5	C2-3 * C3-4	C2-3 * C4-5	C3-4 * C4-5	C2-3 * C3-4 * C4-5
Active TrPs	Masticatory muscles	C2-3 mild	C3-4 mild	1.00 ± 1.41	0.50 ± 0.71	0.50 ± 0.71	0.005*	0.422	0.387	0.650	0.927	0.787	0.290
			C3-4 moderate	0.10 ± 0.01	0.80 ± 1.10	0.10 ± 0.01							
			C3-4 severe	0.50 ± 0.71	0.11 ± 0.01	0.50 ± 0.71							
		C2-3 moderate	C3-4 mild	2.05 ± 2.83	2.0 ± 0.1	0.60 ± 0.89							
			C3-4 moderate	0.33 ± 0.51	0.85 ± 1.37	1.88 ± 1.45							
			C3-4 severe	2.50 ± 0.71	0.10 ± 0.01	1.94 ± 1.48							
		C2-3 severe	C3-4 mild	2.05 ± 2.83	2.50 ± 0.71	4.50 ± 0.11							
			C3-4 moderate	4.50 ± 0.11	2.0 ± 1.41	3.20 ± 1.79							
			C3-4 severe	4.50 ± 0.11	4.50 ± 0.11	2.67 ± 1.78							
	Cervical muscles	C2-3 mild	C3-4 mild	0.50 ± 0.71	0	0	0.009*	0.251	0.409	0.035*	0.195	0.661	0.364
			C3-4 moderate	0	1.60 ± 3.58	2.0 ± 0.0							
			C3-4 severe	0	1.50 ± 0.71	0.50 ± 0.71							
		C2-3 moderate	C3-4 mild	0	0	1.50 ± 0.01							
			C3-4 moderate	0	0.88 ± 2.43	3.56 ± 3.35							
			C3-4 severe	2.00 ± 0.01	0	4.24 ± 2.66							
		C2-3 severe	C3-4 mild	9.00 ± 1.41	5.00 ± 1.41	8.00 ± 0.01							
			C3-4 moderate	2.50 ± 2.12	1.0 ± 1.41	5.60 ± 3.85							
			C3-4 severe	7.0 ± 4.24	9.0 ± 1.41	5.83 ± 3.16							
Latent TrPs	Masticatory muscles	C2-3 mild	C3-4 mild	1.00 ± 1.41	0	1.50 ± 0.71	0.040	0.110	0.429	0.001*	0.470	0.653	0.517
			C3-4 moderate	0.50 ± 0.71	2.20 ± 1.48	2.50 ± 0.71							
			C3-4 severe	0.50 ± 0.71	0	0.50 ± 0.71							
		C2-3 moderate	C3-4 mild	1.00 ± 1.41	1.00 ± 1.41	0.20 ± 0.45							
			C3-4 moderate	0.17 ± 0.41	0.45 ± 0.85	0.56 ± 1.15							
			C3-4 severe	1.00 ± 0.15	0	0.65 ± 1.11							
		C2-3 severe	C3-4 mild	2.50 ± 2.12	0.50 ± 0.71	0.50 ± 0.71							
			C3-4 moderate	0	0	0							
			C3-4 severe	0.50 ± 0.71	1.00 ± 0.15	0.17 ± 0.58							
	Cervical muscles	C2-3 mild	C3-4 mild	0	0	0	0.339	0.793	0.977	0.458	0.713	0.080	0.500
			C3-4 moderate	0	0.40 ± 0.89	0.50 ± 0.71							
			C3-4 severe	0.50 ± 0.71	0.50 ± 0.71	0.50 ± 0.71							
		C2-3 moderate	C3-4 mild	0	0	0							
			C3-4 moderate	0.67 ± 1.21	0.48 ± 1.50	1.00 ± 2.19							
			C3-4 severe	1.00 ± 0.15	0	2.24 ± 0.97							
		C2-3 severe	C3-4 mild	1.00 ± 0.15	0.50 ± 0.71	0							
			C3-4 moderate	0.50 ± 0.71	0.50 ± 0.71	0.80 ± 1.30							
			C3-4 severe	0	0	0.33 ± 0.89							

TrP, trigger point; C2, the second vertebra; C3, the third vertebra; C4, the forth vertebra; C5, the fifth vertebra; *, interaction.
Descriptive values are shown as mean ± SD or median.
Data obtained from three-way repeated measure ANOVA.
**$P < 0.001$ by three-way repeated measure ANOVA.
* $P < 0.05$.

due to cervical degeneration may induce increased masseter muscle activities which may have a role in the development of active TrPs in masticatory muscles.

Proposing reproducible and reliable method for measuring natural head position is quite an important task for orofacial pain specialists and orthopedic surgeons. Several methods for recording natural head posture have been proposed including taking a lateral view photograph and use of cephalostat. The latter one has been regarded as more accurate and reproducible method for recording head postures and its clinical utility has been also well-known (Armijo-Olivo et al., 2006; Cassi et al., 2016). However, adjusting cephalostat and applying ear rods to participants during positioning the head may cause the postural alterations of participants. Previous studies showed altered craniocervical angle when cephalostat was applied and suggested that there was slight tendency for posterior rotation of the head and a decrease of the cervical spine lordosis (Armijo-Olivo et al., 2006; Ferrario, Sforza, Germanò, Dalloca, & Miani, 1994). Nonetheless, one of these studies also suggested that this change was so small as to be clinically insignificant, because the remaining measurements in this study including occipital-atlas distance, atlas-axis distance, and Cobb angle did not show significant differences between values measured using cephalostat and those measured without cephalostat. Furthermore, the capture of a head position while taking a radiograph or photograph without the use of a cephalostat may cause distortion of the image and interference

Table 5
Correlations between the head and neck postures and the number of TrPs in masticatory and cervical muscles.

	OPT-CVT	BaC3ai	C0-1	C1-2	Hyoid triangle
Number of active TrPs in masticatory muscle	0.510**	0.311**	−0.218*	−0.360*	−0.014
Number of active TrPs in cervical muscle	0.602**	0.123	−0.268**	−0.272**	0.057
Number of latent TrPs in masticatory muscle	−0.092	−0.108	−0.046	−0.017	−0.096
Number of latent TrPs in masticatory muscle	0.089	0.035	−0.061	−0.147	−0.123

OPT, posterior tangent to the odontoid process through inferior posterior point of C2; CVT, posterior tangent to the odontoid process through inferior posterior point of C4; Ba-C3ia, the distance between basion (Ba) and the most inferior-anterior point on the body of the third vertebra (C3ia) ; C0-1, the distance between base of the occiput and the posterior arch of the atlas; C1-2, the distance between the posterior arch of the atlas and the spinous process of the second vertebra; hyoid triangle, the height of the triangle made by three points, the most superior and anterior point of the hyoid (H), the inferior and anterior point of the third vertebra (C3ia), and retrognathion (RGN); TrP, trigger point.

* $P < 0.05$.

** $P < 0.01$ by Pearson's correlation analysis.

of the reproducibility of the recording. Therefore, applying cephalogram for measuring head and neck postures has been regarded as acceptable method for previous studies due to its reproducibility, reliability, and clinical utility.

The present study has several limitations. First, owing to a relatively small sample size, the power of statistical significance was inevitably compromised. Second, given that this is a cross-sectional study, it cannot provide information regarding the cause and effect relationships among cervical degeneration, myofascial pain in cervical and masticatory muscles, and head and neck posture. Finally, because this study was a tertiary medical center based study, it could provide limited information regarding the relationships among cervical degeneration, MFP in the craniocervical musculature, and head and neck postures in ordinary elderly individuals. Future prospective community-based studies with larger samples should be conducted to further elucidate the role of cervical spine degeneration on head posture and the development of myofascial TMD and cervical pain.

5. Conclusion

The results from the present study demonstrated that elderly individuals with myofascial TMD and cervical pain presented more severe cervical degeneration and FHP and higher number of TrPs in craniocervical musculatures than those with only myofascial TMD. Degenerative changes in the cervical spine appeared to be related to altered head and neck postures and development of active TrPs in the masticatory and cervical musculature. Therefore, a comprehensive and integrated understanding of the masticatory and cervical system is warranted for the proper management of elderly patients with TMD and cervical spine disorders.

Disclosures and acknowledgement

The research protocol was reviewed in compliance with the Helsinki Declaration and approved by the Institutional Review Board of the University Hospital (AJIRB-MED-MDB-18-191) on July, 3, 2018.

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