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RESEARCH ARTICLE

Asymmetry of dental or joint anatomy or impaired chewing function contribute to chronic temporomandibular joint disorders

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ABSTRACT

Introduction: The etiologies of most chronic temporomandibular joint disorders are unknown. However, an association between habitual chewing on a particular side and chronic temporomandibular joint disorders has been reported.

The aim of this study was to investigate the differences between sides (affected vs unaffected) of biodynamic factors (including lateral dental guidance determined by dental anatomy) or condylar path angles (determined by temporomandibular joint morphology) and chewing function (physiological alternate chewing vs single habitual chewing side). The study scope was to investigate possible etiological factors to improve the understanding of temporomandibular joint disorders.

The null hypothesis was that no difference would be found between sides that are or are not affected by chronic temporomandibular joint disorders in chewing function or in levels of dental or temporomandibular joint remodeling.

Methods: This cross-sectional, double-blind study involved 24 adults with substantial, chronic, unilateral symptoms diagnosed as temporomandibular joint disorders. Chewing function, temporomandibular joint remodeling (using axiography) and dental anatomy (lateral guidance angles using kinesiography) were assessed.

Results: Habitual chewing on one particular side was observed in 17 of 24 participants; significantly more ($n = 15$) chewed on the affected side than on the unaffected side ($P = 0.002$ in a two-tailed Fisher's exact test; risk estimate = 4.5; 95% CI 1.326–15.277). The condylar path (CP) angle was steeper on the affected side than on the unaffected side (mean (standard deviation) = 50.52° (9.98°) versus 45.50° (7.98°); $P = 0.002$ in a two-tailed t-test). The lateral guidance (LG) angles were flatter on the affected side in all 24 participants.

Conclusion: Our results suggest that habitual chewing on one side may be associated with increasing condylar path, with flattening lateral guidance angles, and also with chronic temporomandibular joint disorder on the habitual chewing side.

Abbreviations: TMJ, temporomandibular joint; TMD, temporomandibular joint disorder; CP, condylar path; LG, lateral guidance; ICC, intraclass correlation coefficient; OR, odds ratio; MRI, magnetic resonance imaging; Ai, asymmetry index.

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1. Introduction

Temporomandibular joint (TMJ) disorders (TMDs) are the main causes of chronic facial pain. Typically, fluctuant jaw pain that increases during chewing hard food is the main symptom of TMDs (De Leeuw and Klasser, 2018), which have been estimated to affect >10 million people in the US (NIDCR Web, 2021). The overall prevalence of TMD pain was reported to be 6.3% among women and 2.8% among men in a study of a US population (Isong et al., 2008), and women with a TMD are more likely to seek for therapy than men. TMDs are mainly unilateral (Diernberger et al., 2008), although both sides of the face can be affected. Diagnosis is most often based on patient history and physical examination (Dworkin and LeResche, 1992; Santana-Mora et al., 2013; Gauer and Semidey, 2015).

The etiologies of TMDs are unknown (Dworkin and LeResche, 1992; Pullinger et al., 1993; Hylander, 2006; Krohn et al., 2018); although, as with other inflammatory diseases, TMJ pathology may be genetic in origin (Smith et al., 2011). The TMJ is subjected to pressure forces during occlusion and during mastication (Breul et al., 1999; Breul, 2007; del Palomar et al., 2008; Santana-Mora et al., 2014), and TMJ overloading has been suggested as an etiologic factor (Tanaka et al., 2008).

Food rheology and diversity have important roles in stimulating the structures of the masticatory system (Hinton, 1981; Rios et al., 2008; Ishida et al., 2009; Wang et al., 2021). Human mastication is regulated by the central nervous system (Mongini, 1980; Pond et al., 1986; Hoogmartens et al., 1987; Poikela et al., 1997; Fanghänel and Gedrange, 2007; Suárez-Quintanilla et al., 2020), which favors one side and then the other. The presence of a preferred chewing side (Hildebrand, 1936; Poikela et al., 1997) is common in individuals with TMD symptoms (Kumai, 1993; Reinhardt et al., 2006; Diernberger et al., 2008; Rios et al., 2008; Yeler et al., 2017) compared with patient populations without TMD symptoms (Tay et al., 1989; Pullinger et al., 1993; Jiang et al., 2015). Previous studies in nonpatients showed no significant difference in side for condylar path (CP) (Kordaß et al., 2019) or lateral guidance (LG) (Ferrario et al., 1992).

The results of experimental studies on animals (Poikela et al., 1997; Zhang et al., 2003) suggest that a unilateral chewing action contributes to TMJ remodeling. Unlike other joints, remodeling is a characteristic specific to the human TMJ, because the articular surfaces are composed of fibrous tissue rather than hyaline cartilage (Standring, 2005). Masticatory muscle forces can influence skull morphology (Toro-Ibacache et al., 2016) and articular parameters can shape the anterior teeth morphology (Oancea et al., 2018). Specific characteristics have been shown to be associated with the side of the jaw exhibiting TMD symptoms (Santana-Mora et al., 2013) or signs (Ferrario et al., 1996). These characteristics include (Fig. 1) TMJ remodeling (steep CP angles), alteration of dental occlusion (flat LG angles), and functional specificity (habitual chewing on the symptomatic side). However, the association of these characteristics was demonstrated by the results of a study in which participants who previously underwent occlusal therapies were included. Occlusal therapies (including orthodontics, orthopedics, fixed prostheses, or surgery) could alter tooth morphology, position, and inclines (LG). Alteration of LG angles seems to lead to the preferential use of the side of the jaw with flatter LG angles (Reinhardt et al., 2006), which could, in turn, be responsible for TMJ remodeling (Kumai, 1993) and ipsilateral symptoms (Santana-Mora et al., 2013). Thus, occlusal therapies are potential confounders for any attempt to determine an association between chewing function and TMD. Dental decay, when painful, promotes the alteration of chewing function. Consequently, the assessment of dynamic and functional factors in individuals after the natural evolution of the stomatognathic system, leading to clinically normal dental articulation (occlusion) and an absence of caries, may facilitate identification of the causes of TMD with chronic, unilateral symptoms.

The null hypothesis in our study was that no difference will be found between the painful (affected) and nonpainful (unaffected) sides of the jaw in terms of chewing function, TMJ remodeling, or LG angles in individuals with normal occlusion and substantial, self-reported, chronic, unilateral TMD pain who have not undergone occlusal therapy (that is, after natural evolution and maturation of the stomatognathic system).

2. Participants and methods

2.1. Ethics approval and consent to participate

This was a diagnostic study with a cross-sectional, double-blind design. Participants were unaware of the purposes of the investigation, and clinicians and assessors were unaware of the participants' conditions. All methods were performed in accordance with the Declaration of Helsinki.

The study was approved by the Autonomic Research Ethics Committee of Galicia: CAEI approval number 2009/017; updated on November 29, 2013. Informed consent was obtained during each screening visit to perform the diagnostic procedures. Information presented here is consistent with the consent obtained.

2.2. Participants

Study participants were enrolled from patients referred to the Maxillofacial Surgery Department at the tertiary care University Hospital of A Coruña (Spain) who were suffering from chronic facial pain with a diagnosis of TMD according to the Diagnostic Criteria for Temporomandibular Disorders (Schiffman et al., 2014). It was carried out between August 2014 and October 2018.

2.3. Inclusion criteria

The participants met the inclusion criteria recommendations stated in the IMMPACT guidelines (Dworkin et al., 2005) for studies on chronic pain. They had substantial chronic (>6 months) self-reported pain, with intensity ranging from four to nine on a graded visual analog scale from zero to 10 (Huskisson, 1974). The dental status and occlusion of the participants was carefully examined. They had a clinically normal, stable, occlusion, Angle Class I, with no or less than 2 mm of displacement in the horizontal plane between the cusps and their antagonist fossas or between the centric occlusion and the maximum intercuspal positions. Of 924 screened individuals, 77 met the inclusion criteria for this study.

2.4. Exclusion criteria

Exclusion criteria followed the IMMPACT guidelines (Schiffman et al., 2014). Additional exclusion criteria were applied for this study, resulting in the exclusion of 26 patients with a bilateral TMD condition and 27 individuals who had undergone orthodontic and/or prosthetic therapy.

After application of the exclusion criteria, the final study group consisted of 17 women and seven men with chronic unilateral TMD, a complete dentition, and normal occlusion who had not undergone any kind of irreversible occlusal therapy and who had natural growth and maturation of their stomatognathic systems. The overall mean (SD) age was 37.29 (11.72) years.

2.5. Primary complaints

Nine of the participants reported facial pain on the right-hand side: eight of them had arthralgia (including seven with concomi-

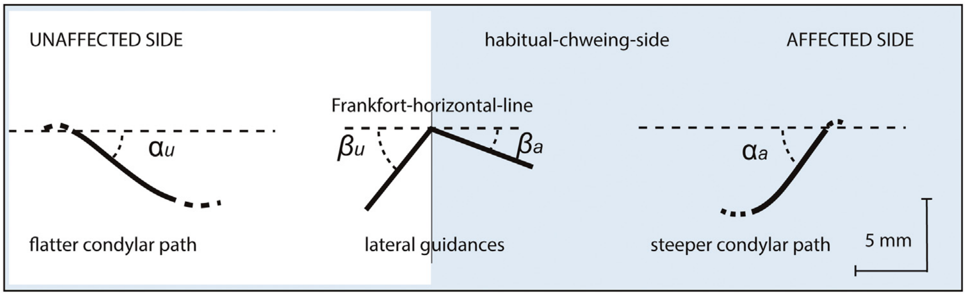

Fig. 1. Free 2D diagram showing sided dimorphism of participants reporting chronic, unilateral symptoms diagnosed as temporomandibular disorders. The affected side exhibits steeper condylar path (higher articular tubercle) and flatter lateral guidance (lower dental inclines) than the unaffected side ($\alpha_u < \alpha_a$; $\beta_u > \beta_a$). All recordings and angles are with respect to the Frankfort horizontal plane. α, Condylar path angle; β, Lateral guidance angle. $_u$, unaffected side; $_a$, affected side.

tant myalgia), and one reported myalgia without arthralgia. Seven individuals with pain on the right-hand side presented with disc displacement (including two with reduction), and one joint showed disc degeneration. Two TMJs showed degeneration. Facial pain was reported on the left side in 15 participants: 12 of them had arthralgia (including eight with concomitant myalgia), and three suffered from myalgia without arthralgia. Disc displacement was observed in 10 of these individuals (including five with reduction); two joints showed condylar hypoplasia, and one joint showed degeneration. Disc absence or degeneration, hypoplasia, and joint degeneration were diagnosed by two independent radiologists using magnetic resonance imaging (MRI) analysis.

2.6. Chewing assessment

Chewing side was diagnosed by observing the chewing of gum (in both the first and subsequent cycles), by kinesiography, and by an interview to determine the current and previous chewing side. Agreement of the results of these tests was considered to indicate a consistent chewing side. The influence of chewing had not been previously assessed in these participants.

2.7. Lateral CP recordings

The axiographic extraoral Gysi method (Gysi and Wayne, 1910), which is reproducible (Preti et al., 1982), was carried out with a kinematic Gerber's face-bow (Kit Registier Ausrustung "C"; Condylator service, Zurich, Switzerland), as reported previously (Santana-Mora et al., 2013). At least three tracings of each TMJ were recorded during lateral jaw motion to the opposite side during the examination visit. At least two of these recordings were required to be identical; otherwise, the recordings were repeated. Images of the CP tracings were digitized in JPG format. For each patient, measurements of two similar tracings were performed, and the mean value was calculated. Tracings were measured independently by a second researcher and showed good interobserver reliability (intraclass correlation coefficient (ICC) = 0.87). The mean of both mean values from the independent assessors was used for comparisons.

2.8. Kinesiographic recordings

Kinesiographic recordings (Ferrario et al., 1996) were performed with a calibrated Model K7 diagnostic system (Myotronics, Kent, WA, USA). Three LG tracings were carried out during the same session, the K7 was zeroed before each recording, and the tracings were almost superimposable. One selected recording was measured by two independent, experienced clinicians (ICC = 0.94), and the mean values were used for comparisons. The LG tracings were exported from the K7 software in JPG format. ImageJ software (Rasband, 2016) was used for measurements. Measurement differences >3° were resolved by discussion or consultation with a third researcher (U.S.).

Table 1
Cross-tabulation of participant numbers for habitual-chewing and temporomandibular joint disorder-pain sides of the jaw.

		Habitual chewing side		
		Right	Left	Total
Pain side	Right	8	0	8
	Left	2	7	9
Total		10	7	17

Seven participants had not an identifiable habitual chewing side, and were excluded from this analysis.

2.9. Statistical analysis

One independent group from the University of Santiago de Compostela (Biostatech®) performed all analyses. Continuous outcomes are reported as the mean (SD). Because they followed normal distributions under the Kolmogorov–Smirnov and Shapiro–Wilks tests, the two-sided Student t-test was used for intra-individual (paired) and interindividual (unpaired) comparisons. Correlations between dichotomous outcomes (chewing and pain sides) were carried out using the Fisher exact, Pearson chi-squared, and Kappa concordance tests. The α level was set at $P = 0.05$.

Sample size estimation was based on a previous report (Santana-Mora et al., 2013). To demonstrate a significant correlation between the habitual chewing side and the symptomatic side, a sample size of 17 participants was sufficient to test the null hypothesis of Kappa = 0, assuming a two-sided test with an $\alpha = 0.05$ and a power of 0.8 to detect a Kappa value >0.7 (Cantor, 1996).

3. Results

3.1. The chewing side was generally the side affected by TMD pain

From a functional viewpoint, 17 (71%) of the 24 participants with unilateral TMD had one consistent habitual chewing side, and in 15 of these 17 participants, the chewing side was the TMD-affected side (Pearson chi-squared test statistic = 10.578; $P = 0.001$; Fisher exact test [two-tailed] $P = 0.002$; Kappa value = 0.767, $P = 0.001$) (Table 1). The risk estimate was 4.5 (95% CI 1.326–15.277). Seven participants had no consistent habitual chewing side and were not included in this analysis.

3.2. CP angles indicate TMJ remodeling on affected side of jaw

One hundred and thirty-eight CP recordings from 46 joints in 24 participants were performed. Mean CP angles on the right side versus the left-side of the jaw, and on the TMD-affected versus the

Table 2
Values of the condylar path (CP) angles.

Outcome	Side of the jaw		95% CI		*P*-value
	Right	Left	Lower	Upper	
CP (n = 22)	48.06° (9.07°)	47.74° (9.62°)	−4.409°	4.273°	0.974
	Affected	Non-affected			
CP (n = 22)	50.52° (9.98°)	45.50° (7.98°)	2.526°	9.338°	**0.002**

Mean (SD) values are shown for CP angles. *P*-values and 95% CIs relate to two-tailed *t*-tests.

Table 3
Values of the lateral guidance (LG) angles.

Outcome	Side of jaw		95% CI		*P*-value
	Right	Left	Lower	Upper	
LG (n = 23)	45.20° (11.46°)	40.62° (12.01°)	−1.288°	9.244°	0.131
	Affected	Non-affected			
LG (n = 23)	38.04° (8.15°)	47.48° (13.10°)	−13.485°	−7.167°	**<0.001**

Mean (SD) values are shown for LG angles. *P*-values and 95% CIs relate to two-tailed *t*-tests.

nonaffected sides, are shown in Table 1. The data for individual participants have been published elsewhere (Data Citation: [datasets] López-Cedrún et al., 2017a, 2017b). The CP angles from two participants were excluded from the data shown in Table 2 because of aberrant form or motion. In one participant, MRI showed condylar flattening, sclerosis of the dome, an osteophyte, and anterior disc displacement without reduction in their left TMJ (symptomatic side). The other excluded participant presented with the absence of a disc in the right TMJ (symptomatic side). Nonaffected side values were used as a control. The left-sided and right-sided mean CP angles did not differ significantly in this group of participants (P = 0.974). However, the mean CP angle was significantly steeper on the affected sides than on the nonaffected sides (P = 0.002). Most participants (17 out of 22 individuals (77%); P = 0.017 by a one-proportion binomial test) had a steeper CP angle on the affected side than on the nonaffected side (two-tailed Fisher exact test P = 0.024; Kappa value = 0.529, P = 0.011; data not shown). Participants with TMD symptoms on the right-hand side had a sixfold greater risk of having a steeper CP angle on the right-hand side than on the left-hand side (odds ratio (OR) = 6.364; 95% confidence interval [CI] 0.940–43.073; data not shown). Participants with TMD symptoms on the left-hand side had a twofold greater risk of a steeper CP angle on the left-hand side than on the right-hand side (OR = 0.404; 95% CI 0.180–0.907; data not shown).

3.3. LG angles indicate lateral dental guidance remodeling on affected side of jaw

Sixty-nine right-side LG and 72 left-side LG recordings in 24 participants were performed. Mean LG angles on the right-side versus the left-side of the jaw, and on the TMD-affected versus the nonaffected sides, are shown in Table 3. The data for individual participants have been published elsewhere (Data Citation: [datasets] López-Cedrún et al., 2017a, 2017b). One LG recording was not included because lateral jaw motion was guided by molar(s) on the contralateral (nonworking) side. The left-sided and right-sided mean LG angles did not differ significantly in this group of participants (P = 0.131). Nonaffected side values were used as a control. The mean LG angles were significantly lower on the affected sides than on the nonaffected sides (P < 0.001). The LG angle was lower on the affected side in all participants studied (data not shown).

Table 4
Values of the indexes from condylar path (CP) and lateral guidance (LG) angles.

	Right pain	Left pain	95% CI		*P*-value
			Lower	Upper	
AiCP (n = 22)	8.41 (9.80)	−4.60 (6.56)	5.750	20.264	**<0.001**
AiLG (n = 23)	−10.23 (8.89)	12.17 (6.29)	−29.010	−15.791	**<0.001**
Equation (n = 21)	1.54 (0.421)	0.73 (0.16)	0.412	1.193	**0.002**

Mean (SD) values are shown for asymmetry indexes (Ai) of CP and LG angles and the outcome of a specific equation. *P*-values and 95% CIs relate to two-tailed *t*-tests. AiCP = [right CP − left CP]/[right CP + left CP]. AiLG = [right LG − left LG]/[right LG + left LG]. *Equation* = [right CP × left LG]/[left CP × right LG].

3.4. Asymmetry indexes enable discrimination between TMD-affected and nonaffected sides of the jaw and determination of the side of habitual chewing

Asymmetry indexes were calculated as intra-individual differences between right-sided and left-sided CP or LG divided by the sums of these values (Table 4). The CP asymmetry index (AiCP) was positive in participants with TMD on the right side, and negative in patients with TMD on the left side, and this difference was significant (P < 0.001 by two-tailed t-test). The LG asymmetry index (AiLG) was negative in participants with TMD on the right side, and positive in participants with TMD on the left side, and this difference was also significant (P < 0.001 by two-tailed t-test). For both AiCP and AiLG, positive values indicate a higher angle on the right side than on the left, whereas negative values indicate a higher angle on the left side than on the right. No between-sex differences were observed in AiCP or AiLG (data not shown).

4. Discussion

Our study was the first to assess dynamic and functional factors in participants with clinically normal dental articulation who had not undergone occlusal therapy and who had substantial unilateral chronic TMD pain. In our study population, all participants with appropriate measurements had a flatter LG angle, and the majority had a steeper CP angle, on the side with chronic TMD pain. Furthermore, if the participants had a habitual chewing side, it was almost always the same as the TMD-affected side.

4.1. The habitual chewing side

There are several reasons why a preferred chewing side need not always be associated with steep CP and flat LG angles. The preferred chewing side may change because of dental decay or other pathologies, some therapies, or during the eruption of the permanent dentition. Such factors can lead to changes in mastication throughout an individual's life and can alter the LG angles in a way that is not always predictable. Moreover, symptomatic TMJs can suffer from internal derangement or severe osteoarthritis leading to aberrant condyle motion, and CP angles can become flatter than expected, as occurred in some individuals.

4.2. Participant selection

Patients with TMD typically request therapy from physicians, pediatricians, neurologists, pain units, or dentists, and the majority obtain pain relief (Gauer and Semidey, 2015). It is probable that the group under study represents the more severe TMD cases among the overall prevalence of TMD. Notably, according to the IMMPACT recommendations (Dworkin et al., 2005), only patients with substantial self-reported pain (with intensity from four to nine on a scale from zero to 10) (Huskisson, 1974) were included. The age difference between the sexes in our population could be because women more frequently seek therapy (Isong et al., 2008).

The influence of occlusal factors in TMDs is controversial (Hylander, 2006; Pullinger et al., 1993). Occlusal therapies may suddenly change the angles of lateral dental guidance and TMJ remodeling (Mongini, 1980). To avoid such effects, only clinically normal, nontreated occlusion with severe chronic unilateral TMD pain were included, which resulted in a homogeneous group and which is one of the strengths of this study.

Neither recording showed sensitivity or specificity to detect TMD. Although these factors were not considered by the relevant guidelines on TMD (Dworkin and LeResche, 1992; Schiffman et al., 2014), the objective and careful measurement of these dynamic peripheral factors could result in interesting diagnostic and/or evolutionary information regarding the stomatognathic system and, in particular, regarding TMDs and chewing function (Hinton, 1981; Zhang et al., 2003; Santana-Mora et al., 2013; Jiang et al., 2015).

Notably, the TMJ (unlike other joints) can be remodeled during function because of the presence of fibrous tissue on the articular surfaces (Standring, 2005), and this remodeling can be measured by recording CP angles (Gysi and Wayne, 1910; Preti et al., 1982). As yet, no unequivocal test has been developed to assess chewing function; moreover, it is not a fixed characteristic, as chewing behavior can change with time. In the present study, we used several tests to attempt to determine whether participants presented one specific and consistent habitual chewing side.

4.3. Condylar path or lateral guidance asymmetry

Our results confirm previous findings in which the CP angle was steeper and the LG angle was flatter on the chewing and TMD-affected sides than on the nonchewing, nonaffected sides (Santana-Mora et al., 2013) or the LG angle was significantly flatter on the same side with the opening deviation, suggesting ipsilateral TMD (Ferrario et al., 1996). An explanation that was previously suggested for the pathophysiology of these findings is that the side toward the jaw moves more horizontally (with a flatter LG) and is the habitual chewing (working) side. The working TMJ mainly acts as a fulcrum, whereas the nonworking TMJ acts as a gliding joint. Condylar motion on the nonworking side enables correct lubrication, and loads are received along a wide gliding surface, probably promoting physiological joint remodeling. At the same time, the more static working-side condyle can suffer from the absence of correct lubrication, muscular hypertrophy, and increased loads on a particular TMJ area, leading to pathological remodeling (increasing the CP angle).

Because lateral dental guidance had not been therapeutically altered in our study population, asymmetric LG angles were likely to have been present for longer than the TMD symptoms. Although it is not possible to determining cause and effect in a cross-sectional study is not possible, our results support the notion that pain is a consequence rather than a cause of the characteristic syndrome of a habitual chewing side. The presence of an ipsilateral chewing side, LG-angle flattening, and elevation of CP angles is likely to occur before the onset of TMD symptoms.

Based on the existing evidence and our own results, we now suggest the concept of dimorphism in chronic unilateral TMD. Relative to the unaffected side, in unilateral TMD that occurs after the natural spontaneous evolution of occlusion, the triad of a steeper CP angle, flatter LG angle, and chewing tends to be seen on the affected side (**Fig. 1**). By contrast, where TMD occurs after occlusal interventions, this triad could be masked and may be influenced by the chronicity and magnitude of the alterations. Moreover, dental decay and tooth mobility may contribute to impaired chewing function, which increases the biological variability and complexity of this poorly understood pathology.

The equation that we have proposed in this paper could be called an equation of chewing biodynamics and was designed to indicate how, ideally, dynamic factors are similar on both sides in individuals who chew unilaterally and alternately on both sides so that:

$$\text{rightCP} \times \text{leftLG} = \text{leftCP} \times \text{rightLG}$$

Our results do not argue against an influence of genetics (Dworkin and LeResche, 1992; Diernberger et al., 2008) on TMD nor against the influence of central factors (such as handedness) (Pond et al., 1986; Nissan et al., 2004) on chewing function but suggest that chewing function and consequently TMD may be influenced by dynamic and functional factors. Comparisons of our results with previous findings are difficult because most previous studies did not assess the triad of chewing function, CP angle, and LG angle or were not limited to participants with a complete dentition and normal occlusion who had not undergone occlusal rehabilitation (Hoogmartens et al., 1987; Tay et al., 1989; Kumai, 1993; Pullinger et al., 1993; Diernberger et al., 2008).

A more horizontal lateral jaw motion (a flatter LG angle) has greater dental contacts, which, in agreement with Hildebrand (Hildebrand, 1936), favors a chewing side. In a previous study (Reinhardt et al., 2006), most patients with TMD had one habitual chewing side, and, in our study, the chewing side was the affected side. Our results agree with those of a previous report that did not exclude participants with orthodontic therapy (Santana-Mora et al., 2013); in our population, all participants had a flatter LG angle on the TMD-affected side than on the unaffected side. Notably, our study excluded individuals who had undergone any kind of occlusal therapy.

4.4. Study limitations

Our study has several limitations. First, among a small study population, the number of men was particularly low, which is consistent with other studies, presumably reflecting the greater number of women who request therapy for TMD

As we did not identify any sex-related differences in the study outcomes, this imbalance should not affect our conclusions. Second, this study was not designed to assess the effect of dominant unilateral chewing function on the periodontium, but none of the participants had >3 mm of periodontal deep probing. Because chewing stimuli are needed to maintain healthy periodontal tissues (Rios et al., 2008), different stimuli on the working and nonworking sides could influence periodontal status. This issue deserves further study.

Third, MRI was only conducted on 16 participants. However, existing evidence indicates that most TMD diagnoses can be made on the basis of anamnesis and clinical exploration (Hoogmartens et al., 1987; Dworkin and LeResche, 1992; Reinhardt et al., 2006; Diernberger et al., 2008; Santana-Mora et al., 2013; Schiffman et al., 2014; Gauer and Semidey, 2015). Fourth, CP tracings can indicate aberrant morphology (inferior concavity), probably suggesting TMJ osteoarthritis (as seen in two participants in this study), or can be short, indicating low condylar mobility. These types of tracing are not suitable for the analyses used in this study. LG tracings typically correspond to anterior ipsilateral dental guidance, but they can be invalidated (as seen in one participant in this study) when lateral jaw motion was guided by the contralateral (nonworking side) molar(s).

Our results suggest that assessment of the characteristics of the stomatognathic system (CP angles, LG angles, and dental-occlusal characteristics) could identify a chronic habitual chewing side more effectively than an interview and/or clinical observation of current chewing in a given subject, although these tests should also be used.

This information could improve diagnostic accuracy and assist in the development of therapeutic plans in overall healthy patients and in those with clinical or subclinical TMD.

Food diversity is known to stimulate masticatory structures (Hinton, 1981; Rios et al., 2008; Ishida et al., 2009; Iwasaki et al., 2015). In accordance with previous findings (Poikela et al., 1997), our results suggest that chewing properly, using one side and then the other side, could also help to avoid or minimize TMD pain and masticatory structure asymmetry.

Further prospective studies are required to elucidate how LG alterations can contribute to switching the chewing side and whether such alterations might have clinical implications for patients with TMD and for healthy individuals. Further studies should also elucidate the influence of impaired mastication during the growing period in children.

5. Conclusions

The results of this study of participants with chronic, unilateral TMD pain who had normal, nontreated occlusion suggest that having one habitual chewing side contributes to homolateral chronic TMD pain and may be diagnosed by measuring CP and LG angles.

Conflict of interests

The authors have no conflicts of interest to declare.

Author contributions

Urbano Santana-Mora, José López-Cedrún, Juán Suárez-Quintanilla, Pablo Varela-Centelles, María Jesús Mora: Conceptualization, Methodology. José Luís Da Silva, Fernanda Figueiredo Costa: Data curation, Resources. María Jesús Mora, José López-Cedrún, Urbano Santana-Penín: Funding acquisition. Urbano Santana-Mora, José López-Cedrún, Urbano Santana-Penín: Project administration, manuscript writing. All authors had full access to the data analysis report and reviewed, contributed to, and approved the final version of the manuscript.

Ethical statement

The study was approved by the Autonomic Research Ethics Committee of Galicia: CAEI approval number 2009/017; updated on November 29, 2013. Informed consent was obtained during each screening visit to perform the diagnostic procedures. All methods were performed in accordance with the Declaration of Helsinki. Information presented here is consistent with the consent obtained.

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Data availability. Data citations

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