J Orofac Orthop (2017) 78:253–258
DOI 10.1007/s00056-016-0079-4

ORIGINAL ARTICLE

Dental Angle class asymmetry and temporomandibular disorders
Asymmetrie der Dentalen Angle-Klasseund Temporomandibuläre Erkrankungen

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Received: 11 August 2016 / Accepted: 16 November 2016 / Published online: 13 January 2017

Abstract
Objectives The aim of this study was to determine whether there is an association between the presence of asymmetric molar or canine Angle classes on the two sides and the presence of temporomandibular joint dysfunction (TMD).
Materials and methods Participants to the study were divided into two groups: TMD group (90 patients) or a control group (58 patients). In the TMD group, clinical assessment for TMD was performed according to the Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) guidelines by the same two trained examiners. In both groups, all subjects underwent an assessment of dental occlusion, focusing on the assessment of bilateral canine and molar Angle class relationship. The study protocol was reviewed and approved by the Institutional Review Board of the University of Padova, and each participant gave written consent to take part in the investigation.
Results TMJ pain was diagnosed in 58, disk displacement in 96, arthrosis in 17, and muscle pain in 46 individuals. Molar Angle class was symmetrical in 86 individuals and asymmetrical in 62 subjects. Molar Angle class was not correlated with any of the TMD diagnoses. Canine Angle class was correlated with TMJ arthrosis. Correlation values with the other TMD diagnoses were low and were not significant.
Conclusions It can be suggested that an association between dental Angle class asymmetry and TMDs does not exist and that the role of dental asymmetries as a factor correlated with the presence of TMD signs and symptoms is minimal.

Keywords Dental malocclusion · Orthodontic treatment · Functional dentistry · Stomathognathic system · Arthrosis · Craniomandibular dysfunction

Zusammenfassung
Ziele Untersucht werden sollte, ob zwischen Asymmetrien der Angle Klasse im Bereich der Molaren und Eckzähne und einer temporomandibulären Dysfunktion („temporomandibular joint dysfunction“, TMD) ein Zusammenhang besteht.
Material und Methoden Die Studienteilnehmer wurden in 2 Gruppen eingeteilt: in eine TMD- (90 Patienten) und eine Kontrollgruppe (58 Patienten). In der TMD-Gruppe wurde die klinische TMD-Evaluierung von 2 ausgebildeten Untersuchern leitlinienkonform erhoben (Diagnostic Criteria for Temporomandibular Disorders, RDC/TMD). Alle Teilnehmenden beider Gruppen unterzogen sich einem Assessment der dentalen Okklusion mit besonderem Fokus auf der Angle-Klasse-Beziehung von Molaren und Eckzähnen auf beiden Seiten. Das Studienprotokoll war von der Ethikkommission der Universität Padua durchgesehen und akzeptiert worden, und jeder Teilnehmende hatte schriftlich sein Einverständnis zur Teilnahme an der Studie erteilt.
Ergebnisse Schmerzen im Bereich des Temporomandibulargelenks (“temporomandibular joint”, TMJ) wurde bei

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58 Patienten diagnostiziert, eine Diskusverlagerungg bei 96, eine Arthrose bei 17 und Muskelschmerzen bei 46. Die Angle-Klasse im Bereich der Molaren war symmetrisch bei 86, asymmetrisch bei 62 Studienteilnehmern. Es bestand keine Korrelation zwischen der Angle-Klasse im Bereich der Molaren und einer der TMD-Diagnosen. Die Angle-Klasse im Bereich der Eckzähne korrelierte mit einer Arthrose im Temporomandibularglenk. Die Korrelationen mit den anderen TMD-Diagnosen waren niedrig und statistisch nicht signifikant.

Schlussfolgerungen Es kann davon ausgegangen werden, dass zwischen einer dentalen Angle-Klasse-Asymmetrie und den temporomandibulären Dysfunktionen keine Assoziation besteht und dass die Bedeutung dentaler Asymmetrien als Hinweisen auf oder als Symptom einer TMD minimal ist.

Schlüsselwörter Dentale Malokklusion · Kieferorthopädische Behandlung · Funktionelle Zahnheilkunde · Stomathognathes system · Arthrose · kraniomandibuläre Dysfunktion

Introduction

Studies of the relationship between features of dental occlusion and temporomandibular disorders (TMD) has been a topic in the dental literature since the early decades of past century [3]. On the one hand, the majority of investigations showed that such a relationship, if existing, is actually weak, thus, claiming for the need to search for other more relevant risk factors for TMD (e.g., psychosocial features, clenching-type bruxism, hormones, genetics) [14, 29, 31]. On the other hand, some professionals still advocate the need to assess dental occlusion of TMD patients in detail and correct it accordingly [28]. The latter viewpoint, despite not being supported by any recent literature reviews or consistently published data [21], is actually quite common among clinicians working in the field of restorative and functional dentistry.

This means that the paradigm shift from peripheral (i.e., occlusal, morphological) to central theories of TMD pathophysiology has not been fully accomplished and that further investigations are needed. In particular, possible areas of interest should be identified within common beliefs that have not actually been explored yet. For example, in the field of orthodontics and functional dentistry, the presence of asymmetry in dental occlusion has always been considered a condition needing treatment in order to restore physiological jaw function [1, 2]. Clinically, an easy-to-assess asymmetry is the presence of different Angle classes on the two interarch sides. In theory, such asymmetry could have potential consequences on both the frontal and sagittal occlusal plane and may be associated with functional demand for adaptation. In practice, it is surprising that the investigations on its relationship with temporomandibular joint (TMJ) disorders are actually scarce [4, 5, 9].

The relationship between occlusion and TMD has been explored as far as several single and multiple occlusal risk factors are concerned [11, 15, 23, 24], but there seems to be lack of data concerning Angle class dental asymmetry. Thus, the present investigation aims to answer the clinical research question of whether there is an association between the presence of asymmetric molar or canine Angle classes on both sides and the presence of TMD. Thus, the frequency of the various Angle classes in a population of TMD patients was compared in a cross-sectional investigation with a matched group of non-TMD individuals.

Materials and methods

Study sample and design

Participants in the study were two groups of age- and sex-matched individuals who were divided into either a study (TMD) or a control group. The study group comprised patients seeking TMD treatment at the Temporomandibular Disorders Clinic, while the control group included subjects seeking dental care at the School of Dentistry of the University of Padova, Italy and had no current or past pain at the TMJ and/or jaw muscles.

TMD patients ($N = 90$) were recruited consecutively and included in the study if they met the following criteria: age between 20 and 40 years; presence of an evaluable interarch canine and/or molar relationship; no history of orthodontic treatment; and absence of any past major (i.e., more extensive than single crowns) prosthetic treatments or occlusal rehabilitations (i.e., occlusal adjustments). The control group ($N = 58$) was recruited according to the same criteria. The presence of asymptomatic joint click sounds was not considered an exclusion criterion for the control group. As described in detail below, standardized guidelines were adopted to assess TMD patients as well as to screen controls for the absence of TMD signs and symptoms [26]. All participants were assessed by the same two trained examiners.

The study protocol was reviewed and approved by the Institutional Review Board of the University of Padova, and each participant gave written consent to take part to the investigation.

TMD assessment

In the TMD group, clinical assessment for TMD was performed according to the Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) guidelines [26] by the

same two trained examiners, under the supervision of the leading investigator with expertise in TMD clinical assessment and research methodology [12, 16].

The assessment focused mainly on diagnosing the presence of joint pain (i.e., DC/TMD diagnosis of arthralgia), disc displacement (i.e., any DC/TMD diagnosis of disc displacement with or without reduction), arthrosis (i.e., DC/TMD diagnosis of temporomandibular joint [TMJ] osteoarthrosis, viz., and degenerative joint disease), and muscle pain (i.e., DC/TMD diagnosis of myofascial pain). Selected imaging techniques were prescribed, when needed, to support the clinical assessment.

Occlusal evaluation

All subjects underwent an assessment of dental occlusion, partly based on protocols adopted in previous studies [19]. The assessment focused on the assessment of bilateral canine and molar Angle class relationship. For statistical purposes, all cases of the so-called head-to-head canine or molar relationship have been considered as class II, and patients were thus grouped as follows, based on the presence of symmetrical or asymmetrical dental class on the two sides: absence of bilaterally evaluable class; presence of bilateral class I; presence of bilateral class II; presence of bilateral class III; presence of class I and class II on the two opposite sides; presence of class I and III on the two sides; presence of class II and III on the two sides. All the above groupings were performed separately for the canine and molar classes (e.g., individuals with molar class II may have canine class I in the case of ectopic first or second bicuspid).

Statistical analysis

Within the whole study sample, the prevalence of each of the above specific Angle class groups was compared between subjects with or without the different TMD diagnoses by means of the phi (ϕ) coefficient. The ϕ coefficient is a measure of the degree of association between two binary variables and is similar to the correlation coefficient in its interpretation. The values range from -1.0 to $+1.0$, indicating different levels of negative or positive correlation. As a general rule for correlation analyses, values higher than 0.7 are considered supportive of a strong positive correlation [20].

Results

Within the whole sample of 148 individuals, TMJ pain was diagnosed in 58, disk displacement in 96, arthrosis in 17, and muscle pain in 46 individuals. As for molar Angle class, it was symmetrical in 86 individuals (i.e., $n = 44$ class I, $n = 22$ class II, $n = 20$ class III) and asymmetrical in 62 subjects (i.e., $n = 22$ class I–II, $n = 9$ class I–III, $n = 4$ class II–III, $n = 27$ not evaluable class on one or both sides). Canine class was symmetrical in 106 subjects (i.e., $n = 58$ class I, $n = 24$ class II, $n = 24$ class III) and asymmetrical in 42 individuals (i.e., $n = 17$ class I–II, $n = 13$ class I–III, $n = 7$ class II–III, $n = 5$ not evaluable class on one or both sides).

Molar Angle class was not correlated with any TMD diagnoses (Table 1). In particular, symmetrical class I, II, or III was found in 32 of 58 subjects with TMJ pain, and in

Tab. 1 Prevalence of the different combinations of molar Angle classes in the various diagnostic groups
Tab. 1 Prävalenz der unterschiedlichen Kombinationen der Angle-Klassen im Bereich der Molaren in den verschiedenen diagnostischen Gruppen. Die Spalte Korrelation enthält die ϕ-Werte

Molar class	TMJ pain		Disk displacement		TMJ arthrosis		Muscle pain	
	Absent ($N = 90$)	Present ($N = 58$)	Absent ($N = 52$)	Present ($N = 96$)	Absent ($N = 131$)	Present ($N = 17$)	Absent ($N = 102$)	Present ($N = 46$)
I	29	15	19	25	41	3	31	13
II	14	8	6	16	21	1	15	7
III	11	9	5	15	17	3	16	4
I–II	14	8	9	13	20	2	14	8
I–III	6	3	3	6	7	2	7	2
II–III	2	2	3	1	4	0	1	3
Not evaluable	14	13	7	20	21	6	18	9
Correlation (significance)	0.120		0.216		0.217		0.192	
Significance	0.906		0.332		0.325		0.484	

Correlation refers to the ϕ values

TMJ temporomandibular joint

Tab. 2 Prevalence of the different combinations of canine Angle classes in the various diagnostic groups
Tab. 2 Prävalenz der unterschiedlichen Kombinationen der Angle-Klassen im Bereich der Eckzähne in den verschiedenen diagnostischen Gruppen. Die Spalte Korrelation enthält die ϕ-Werte

Canine class	TMJ pain		Disk displacement		TMJ arthrosis		Muscle pain	
	Absent ($N = 90$)	Present ($N = 58$)	Absent ($N = 52$)	Present ($N = 96$)	Absent ($N = 131$)	Present ($N = 17$)	Absent ($N = 102$)	Present ($N = 46$)
I	33	25	22	36	55	3	41	17
II	13	11	6	18	24	0	14	10
III	14	10	5	19	21	3	18	6
I–II	12	5	7	10	14	3	11	6
I–III	11	2	8	5	9	4	11	2
II–III	4	3	3	4	6	1	4	3
Not evaluable	3	2	1	4	2	3	3	2
Correlation (significance)	0.178		0.238		0.389		0.165	
Significance	0.584		0.212		0.001		0.673	

Correlation refers to the ϕ values

TMJ temporomandibular joint

54 of 90 subjects without TMJ pain ($\phi = 0.120$; $p = 0.906$), while the prevalence was 56 of 96 in subjects with and 22 of 52 without disc displacement ($\phi = 0.216$; $p = 0.332$), 8 of 17 in subjects with and 79 of 131 without arthrosis ($\phi = 0.217$; $p = 0.325$), and 24 of 46 in subjects with and 62 of 102 without muscle pain ($\phi = 0.192$; $p = 0.484$).

Canine Angle class was correlated with TMJ arthrosis (Table 2), with a 6 of 17 prevalence of symmetrical class in subjects with and 100 of 131 without arthrosis ($\phi = 0.389$; $p = 0.001$). Correlation values with the other TMD diagnoses were low, and not significant: symmetrical class was found in 46 of 58 subjects with TMJ pain, and in 60 of 90 subjects without TMJ pain ($\phi = 0.178$; $p = 0.584$), while the prevalence was 73 of 96 in subjects with and 33 of 52 without disc displacement ($\phi = 0.238$; $p = 0.212$), and 33 of 46 in subjects with and 73 of 102 without muscle pain ($\phi = 0.165$; $p = 0.673$).

Discussion

The role of dental occlusion as the main risk factor for disorders of the temporomandibular joint and jaw muscles has been progressively dismantled over the past decades [30], but it seems to be still alive in some clinical practitioners' minds, as a quick look at dental websites or non-scientific journals can easily unveil. The reasons for this missed paradigm change from a dentally to a centrally oriented management of TMD and orofacial pain have been addressed several times [10, 13, 25]. In short, it may have to do with the unproven transfer of some prosthodontics and/or orthodontic dogmas into the TMD field, as if some occlusal treatment goals prosecuted by prosthodontists or orthodontists were fundamental to prevent damage to the TMJ [6].

In the literature, applying multiple variable models to the study of abnormalities of dental occlusion and TMD has repeatedly shown, at best, a weak association between the two conditions [31]. Notwithstanding that, it could be argued that data drawn from investigations adopting complex statistical approaches are not so easy to manage for the average practitioners. Thus, it was recently suggested that descriptive studies may be even more useful to provide a take-home message on the topic [17]. In the field of orthodontics, asymmetry of dental occlusion, grossly identified by the presence or absence of the same canine and molar Angle class on the two sides, has always been considered a condition requiring treatment [7, 22, 27, 32], but its actual correlation with disorders of the stomatognathic system has never been assessed.

Within these premises, this investigation had a simple design, focusing on the hypothesis that asymmetry of dental occlusion, viz., different Angle classes on the two sides, is correlated with TMD. In general, findings refute the study hypothesis, with a minor exception (i.e., asymmetric canine class and TMJ arthrosis). In short, the presence of the same Angle class on the left and right side has a similar prevalence than asymmetric class in both TMD cases and controls. Among the several possible combinations of Angle classes (i.e., bilateral class I, II, III, or asymmetrical presence of class I–II, I–III, II–III), there are no patterns that correlate with any of the TMD diagnoses under investigation, neither at the canine or the molar level.

The only exception, viz., the correlation between the canine class and arthrosis, is likely due to the very small size of the arthrosis group. The significant correlation is indeed due to the arthrosis diagnosed in three of the only five subjects with a not evaluable canine class on one side due to teeth migration or rotation. Despite being potentially interesting, the functional meaning and clinical relevance of this finding has to be explored in future studies.

This study has several limitations, mainly related with the single variable analysis and the absence of any attempts to discriminate between dental- and skeletal-based asymmetries as well as with the absence of information on other relevant associated factors with TMD (e.g., psychological assessment). The single variable analysis might have been a limitation to the validity of findings in the case that some potentially relevant correlations were found, since further exploration of data via multiple variable approaches, which best depict biological models, should have been performed [23]. However, with the above minor exception, the data do not support the need for going deeper into their analysis, given the absence of correlations between dental asymmetries and TMD here described. On the other hand, the inclusion of unspecifically diagnosed asymmetries may be a shortcoming from an orthodontic perspective. While an evaluation of the patients' skeletal features as well as an assessment of compensation factors associated with mandibular deviation and asymmetric Angle class should have added some important information for further discrimination between patients' subgroups from an orthodontic perspective, it should also be pointed out that this study provides the first data on the topic and, as such, they could be used to refine methodological strategies in the near future.

To our knowledge, despite the many studies investigating the association of temporomandibular disorders with several purported abnormalities of dental occlusion (e.g., cross bite, open bite, deep bite, large anterior overjet, dental midline discrepancy, interferences during jaw movements, slides from centric relation to maximum intercuspation), the presence of asymmetries has never been assessed. The findings of this investigation must be interpreted with caution, but it could be suggested that, based on the weak, if existing, correlation with TMD, orthodontic indications for correcting dental asymmetries should not be justified with the need to either prevent or treat disorders of the TMJ and the jaw muscles. This is particularly important in the light of the number of papers focusing on the possible strategies, instead of the reasons, to correct mandibular asymmetries [8]. As already pointed out in the TMD and orofacial pain literature, risk factors for diseases are currently searched outside, rather than inside, the dental field (OPPERA summary). Within the occlusion–TMD field, important clinical implications have come from recent studies suggesting that the correction [18] and even the failed attempt of correction of malocclusions [16] is neutral as far as the effects on TMD is concerned. This means that, from an orthodontic perspective, studies on the prevalence of natural occlusion features in orthodontically untreated adult populations are fundamental to unveil the natural course of purported malocclusions and their association with the incidence of signs and symptoms of disease. Future studies on the topic are encouraged to adopt a careful approach to evaluate the pathology-related indications for orthodontic treatment.

Conclusions

The present investigation was designed to obtain greater understanding into the possible association between the presence of asymmetric molar or canine Angle classes on two sides and the presence of temporomandiblar disorders. Within the limits of this study, it can be suggested that such an association does not exist and that the role of dental asymmetries as a factor correlated with the presence of TMD signs and symptoms is minimal.

Compliance with ethical standards

Conflict of interest D Manfredini, L. Lombardo, and G. Siciliani state that they have no conflicting interests.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

References

1. Bishara SE, Burkey PS, Kharouf JG (1994) Dental and facial asymmetries: a review. Angle Orthod 64(2):89–98
2. Chang FH, Chen KC, Shiau YY (1997) The importance of determination of jaw position in orthodontic diagnosis and treatment planning for adult patients. Dent Clin North Am 41(1):49–66
3. Costen JB (1934) A syndrome of ear and sinus symptoms dependent upon disturbed function of the temporomandibular joint. Ann Otol Rhinol Laryngol 43:1–15
4. D'Ippolito S, Ursini R, Giuliante L, Deli R (2014) Correlations between mandibular asymmetries and temporomandibular disorders (TMD). Int Orthod. 12:222–238
5. Fushima K, Inui M, Sato S (1999) Dental asymmetry in temporomandibular disorders. J Oral Rehabil 26:752–756
6. Greene CS, Obrez A (2015) Treating temporomandibular disorders with permanent mandibular repositioning: is it medically necessary? Oral Surg Oral Med Oral Pathol Oral Radiol. 119:489–498
7. Ireland AJ, Cunningham SJ, Petrie A, Cobourne MT, Acharya P, Sandy JR, Hunt NP (2014) An index of orthognathic functional treatment need (IOFTN). J Orthod. 41:77–83

8. Ishizaki K, Suzuki K, Mito T, Tanak EM, Sato S (2010) Morphologic, functional, and occlusal characterization of mandibular lateral displacement malocclusion. Am J Orthod Denotfac Orthop 137:454.e1-e9
9. Kahn J, Tallents RH, Katzberg RW, Ross ME, Murphy WC (1999) Prevalence of dental occlusal variables and intraarticular temporomandibular disorders: molar relationship, lateral guidance, and nonworking side contacts. J Prosthet Dent 82:410–415
10. Klasser GD, Greene CS (2009) The changing field of temporomandibular disorders: what dentists need to know. J Can Dent Assoc 75:49–53
11. Landi N, Manfredini D, Tognini F, Romagnoli M, Bosco M (2004) Quantification of the relative risk of multiple occlusal variables for muscle disorders of the stomatognathic system. J Prosthet Dent 92(2):190–195
12. Manfredini D, Ahlberg J, Winocur E, Guarda-Nardini L, Lobbezoo F (2011) Correlation of RDC/TMD axis I diagnoses and axis II pain-related disability. A multicenter study. Clin Oral Investig 15:749–756
13. Manfredini D, Bucci MB, Montagna F, Guarda-Nardini L (2011) Temporomandibular disorders assessment: medicolegal considerations in the evidence-based era. J Oral Rehabil 38:101–119
14. Manfredini D, Lobbezoo F (2010) Relationship between bruxism and temporomandibular disorders: a systematic review of literature from 1998 to 2008. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010(109):e26–e50
15. Manfredini D, Peretta R, Guarda-Nardini L, Ferronato G (2010) Predictive value of combined clinically diagnosed bruxism and occlusal features for TMJ pain. Cranio. 28:105–113
16. Manfredini D, Perinetti G, Guarda-Nardini L (2014) Dental malocclusion is not related to temporomandibular joint clicking: a logistic regression analysis in a patient population. Angle Orthod 84:310–315
17. Manfredini D, Perinetti G, Stellini E, Di Leonardo B, Guarda-Nardini L (2015) Prevalence of static and dynamic dental malocclusion features in subgroups of temporomandibular disorder patients: Implications for the epidemiology of the TMD-occlusion association. Quintessence Int 46:341–349
18. Manfredini D, Stellini E, Gracco A, Lombardo L, Nardini LG, Siciliani G (2015) Orthodontics is temporomandibular disorders-neutral. Angle orthod **(Epub ahead of print)**
19. Manfredini D, Visscher C, Guarda-Nardini L, Lobbezoo F (2012) Occlusal factors are not related with self-reported bruxism. J Orofac Pain. 26:163–167
20. McNemar Q (1962) Psychological statistics. Wiley, New York
21. Okeson JP (2015) Management of temporomandibular disorders and occlusion, 7th edn. CV Mosby, St. Louis
22. Pinho T, Pacheco JJ, Salazar F (2014) Treatment of an asymmetric malocclusion: a case report. Aust Orthod J. 30:72–80
23. Pullinger A (2013) Establishing better biological models to understand occlusion. I: TM joint anatomic relationships. J Oral Rehabil 40:296–318
24. Pullinger AG, Seligman DA (2000) Quantification and validation of predictive values of occlusal variables in temporomandibular disorders using a multifactorial analysis. J Prosthet Dent 83:66–75
25. Reid KI, Greene CS (2013) Diagnosis and treatment of temporomandibular disorders: an ethical analysis of current practices. J Oral Rehabil 40:546–561
26. Schiffman E, Ohrbach R, Truelove E, Look J, Anderson G, Goulet JP et al (2014) International RDC/TMD Consortium Network, International association for Dental Research; Orofacial Pain Special Interest Group, International Association for the Study of Pain. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for Clinical and Research Applications: recommendations of the International RDC/TMD Consortium Network* and Orofacial Pain Special Interest Group†. J Oral Facial Pain Headache. 28:6–27
27. Shroff B, Siegel SM (1998) Treatment of patients with asymmetries using asymmetric mechanics. Semin Orthod. 4:165–179
28. Slavicek R (2011) Relationship between occlusion and temporomandibular disorders: implications for the gnathologist. Am J Orthod Dentofac Orthop.139(1):10, 12, 14 passim
29. Suvinen ti, kemppainen P, Könönen M, Dworkin SF (2005) Review of aetiological concepts of temporomandibular pain disorders: towards a biopsychosocial model for integration of physical disorder factors with psychological and psychosocial illness impact factors. Eur J Pain 9:613–33
30. Türp JC, Greene CS, Strub JR (2008) Dental occlusion: a critical reflection on past, present and future concepts. J Oral Rehabil 35:446–453
31. Türp JC, Schindler H (2012) The dental occlusion as a suspected cause for TMDs: epidemiological and etiological considerations. J Oral Rehabil 39:502–512
32. Van Steenbergen E, Nanda R (1995) Biomechanics of orthodontic correction of dental asymmetries. Am J Orthod Dentofac Orthop 107(6):618–24