[1]Zavod za stomatološku protetiku ◆ Stomatološki fakultet
Sveučilište u Zagrebu ◆ Gundulićeva 5 ◆ 10000 Zagreb
[2]Zavod za dentalnu antropologiju ◆ Stomatološki fakultet
Sveučilište u Zagrebu ◆ Gundulićeva 5 ◆ 10000 Zagreb
[3]Klinički zavod za dijagnostičku i intervencijsku radiologiju
Klinički bolnički centar "Sestre milosrdnice" ◆ Vinogradska 29 ◆ 10000 Zagreb
[4]Poliklinika za fizikalnu medicinu i rehabilitaciju ◆ Matice hrvatske bb ◆ 10410 Velika Gorica
[5]Katedra za medicinsku statistiku, epidemiologiju i medicinsku informatiku
Škola narodnog zdravlja "Andrija Štampar" ◆ Medicinski fakultet
Sveučilište u Zagrebu ◆ Rockefellerova 4 ◆ 10000 Zagreb

OSTEOARTHRITIC TEMPOROMANDIBULAR JOINT CHANGES CONFIRMED BY MAGNETIC RESONANCE IMAGING

OSTEOARTRITIČNE PROMJENE TEMPOROMANDIBULARNOG ZGLOBA POTVRĐENE MAGNETSKOM REZONANCIJOM

Tomislav Badel[1] ◆ Ivana Savić Pavičin[2] ◆ Dijana Zadravec[3] ◆ Ladislav Krapac[4] ◆ Josipa Kern[5]

Summary

Clinical and radiological findings were compared between the patients with osteoarthritis (OA) of temporomandibular joint (TMJ) with or without disc displacement (DD), and asymptomatic volunteers. This study included 30 patients with OA of TMJs (mean age 52.6). All the patients were examined clinically by manual functional analysis and using magnetic resonance imaging. The inclusion criteria for patients comprised: pain referred to the TMJ and/or crepitation in the TMJ. A second group consisted of 20 asymptomatic dental school students (mean age 23.5). There is a statistically significant difference between degenerative changes of the condyle of TMJs with and without clinical signs of OA of patients (p=0.009). In 28% of osteoarthritic joints, flattening of condylar joint surfaces was observed and 17.4% of the joints were without clinical signs of OA. Osteophyte formations were found in 8% of asymptomatic and 25.7% of osteoarthritic patients' joints. There is a statistically significant difference between patients' TMJs with and without OA (p=0.0003): pronounced shape loss and severe sclerosation of the articular eminence were found in 12% of the joints without OA, and 42.9% of joints with OA. There is no difference between students' joints and patients' TMJs without OA (p=0.804). The most common imaging findings of osteoarthritic TMJs were sclerosis of the condyle and osteophyte formation.

Keywords

osteoarthritis, temporomandibular joint, magnetic resonance imaging

Sažetak

Uspoređeni su klinički i radiološki nalazi bolesnika s osteoartritisom temporomandularnog zgloba s ili bez pomaka diska te asimptomatskih dobrovoljaca. Istraživanje je obuhvatilo 30 bolesnika s osteoartritisom temporomandibularnog zgloba (prosječne dobi 52,6 godina). Svi bolesnici pregledani su klinički manualnom funkcijskom analizom i uporabom magnetske rezonancije. Kriterij kojim su obuhvaćeni bolesnici bili su: bol vezan za temporomandibularni zglob i/ili krepitacija u istom zglobu. Drugu skupinu činilo je 20 asimptomatskih studenata dentalne medicine (prosjek dobi 23,5 godina). Postojala je statistički značajna razlika između degenerativnih promjena kondila zglobova bolesnika s i bez znakova osteoartritisa (p=0,009). U 28% osteoartritičnih zglobova bila je deplanacije zglobnih površina kondila, kao i u 17,4% zglobova bez kliničkih znakova osteoartritisa. Osteofitične tvorbe pronađene su u 8% asimptomatskih i 25,7% osteoartritičnih zglobova bolesnika. Postojala je

doc.dr.sc. Tomislav Badel
Zavod za stomatološku protetiku ◆ Stomatološki fakultet ◆ Sveučilište u Zagrebu ◆ Gundulićeva 5 ◆ 10000 Zagreb
e-mail: badel@sfzg.hr

statistički značajna razlika među zglobovima bolesnika s i bez osteoartritisa (p=0,0003): izraženi gubitak kontura i izražena sklerozacija zglobne kvržice nađeni su u 12% zglobova bez osteoartritisa i 42,9% zglobova s osteoartritisom. Nije bilo razlike između zglobova studenata i zglobova bolesnika bez osteoartritisa (p=0,804). Najčešći nalaz na snimkama osteoartritičnih zglobova bile su skleroza kondila i osteofitične tvorbe.

Ključne riječi

osteoartritis, temporomandibularni zglob, magnetska rezonancija

Introduction

Osteoarthritis (OA) and disc displacement (DD) of temporomandibular joint (TMJ) belong to the arthrogenic group of temporomandibular disorders (TMD), which are the most common cause of orofacial musculoskeletal pain. Multifactorial etiologic theory of TMD was described under various physical and psychological factors, which could be potentially significant in development of TMD forms (1,2).

Osteoarthritis is a low-inflammatory arthritic condition that results in various degenerative joint changes clinically manifested as joint noises (crepitation), arthralgia, and limited opening of the mouth (3).

Radiologically supported studies emphasized a controversy with respect to the relationship with: DD without reduction (4-8), clinically and radiologically confirmed signs of OA of TMJ (6,7,9,10), degenerative changes of TMJs in asymptomatic volunteers (10-13), and relation to the younger patients part of population (14).

Manual functional analysis (MFA) according Bumann and Groot Landeweer (15) is a collection of manual techniques for clinical diagnostics of origin of pain related to TMD, and includes differentiation between myogenic and arthrogenic (for example, DD and OA) subgroups of TMD. In the TMJ diagnostics magnetic resonance imaging (MRI) is a gold standard compared to clinical diagnostics or other radiological methods (panoramic radiography). MRI is predominant in soft tissue diagnostics and computed tomography (CT) can be additionally useful in detecting hard tissue changes (16).

The aim of this study was to compare clinical and radiological findings in patients with unilateral or bilateral OA of TMJ with or without DD, and asymptomatic volunteers without DD.

Materials and methods

This study included 30 patients with OA of TMJs (median age 53, mean age 52.57±17.10 with range: 19-82; 83% women) from a group of 140 TMD patients (17). All the patients were consecutively examined between January 2001 and December 2008 during clinical examination using MFA (15) and Research Diagnostic Criteria (RDC) for TMD (18) at the Department of Prosthodontics. Definite selection was performed on the basis of diagnostics by MRI for all subjects of this study. The patients' joints with OA or without OA were compared with a group of asymptomatic volunteers consisting of 20 selected dental school students (median age 23, mean age 23.45±1.47 with range: 21-27; 70% women) without any clinical signs or history of DD or any kind of degenerative joint disease confirmed by MRI (19). Asymptomatic volunteers were not undergoing orthodontic or prosthodontic treatments at the time and there were no prior data on orofacial trauma or rheumatoid disease.

The inclusion criteria for patients comprised two conditions: pain referred to the TMJ and/or crepitation-'gravel'-like or 'cracking' effect in the TMJ. Clinical diagnostics using MFA (15) included the dynamic compressions in cranial direction during which the patient performed protrusive movements and mouth opening. Pain, pathologic noise and additional limited mouth opening were noticed upon dynamic compressions. Passive compressions were used by the therapist to move the condyles and in such a way to examine the painful sensation in the retrodiscal tissue. Pain intensity was rated on a visual-analogue scale (VAS 0-10, 0 means no pain, 10 means the strongest pain) (20).

Active movement of the maximal mouth opening was measured by a gauge in millimeters, between markings on the labial surface of the lower central incisor in the plane of the upper central incisor overbite.

All participants of this research were personally informed about the aims and examination methods and gave their written consent to participate according to the protocol approved by the Ethics Committee of the School of Dental Medicine, University of Zagreb. Apart from the gathering of personal data, the consent referred to the use of MRI as the gold standard as well as other techniques of radiologic examinations of TMJs. The patients underwent conventional radiography of TMJ prior to visiting the Department of Prosthodontics, which was used as an additional confirmation of OA diagnosis within this study, whereas CT, with the patients' consent, was used as a comparative diagnostic method with respect to the positive MRI finding.

MRI and panoramic imaging were used for all subjects in this study. CT and conventional radiography

of TMJ were also used on 56.6% of the patients' sample. The scans were interpreted using the criteria for OA diagnosis on every selected parasagittal slice of TMJ; with presence or absence of the following degenerative bone changes. For articular eminence: no osteoarthritic signs (normal shape and density), moderate shape loss/severe sclerosation, pronounced shape loss/severe sclerosation. For condyle bone: no osteoarthritic signs (normal shape and density), deplaned shape, moderately sclerosed areas, pronounced sclerosed areas, and osteophyte formation and pronounced sclerosed areas (subchondral pseudocyst). Degenerative bone changes were also observed in TMJs of asymptomatic patients (that is, patients without clinical signs of OA).

Physiological disc position was confirmed in patients' TMJs with OA using the following criteria: the intermedial part of the disc was positioned within the shortest span of the osseous contours of the ventrocranial part of the condyle and the articular eminence.

The MRI diagnostics of both TMJs of all the subjects was performed by T1 weighted (TR 450/TE 12; matrix 256 x 192; 160 x 160 field of view) and T2 weighted images (TR 3000/TE 66; matrix 389 x 512; 190 x 190 field of view), and seven slices of images with a 3 mm thickness) using the magnet on a "Harmony" (Siemens, Erlangen, Germany), at magnetic field magnitude of 1T. Bilateral MR images of the TMJs were obtained simultaneously on the individually established coronal and parasagittal planes of the images on the basis of a previously performed axial scout.

The statistical data analysis was performed with the STATISTICA and SAS programs. The left and the right TMJs of each person were presented as two separate entities within the data analysis. Three subgroups of joints were formed with respect to the finding of degenerative changes: patients' joints with clinical signs of OA, patients' joints without clinical signs of OA, and asymptomatic volunteers' joints. Data were analyzed by t-test (mouth opening measurement), chi-squared test (comparison of all subgroups of joints and patients regarding degenerative changes of articular eminence; comparison within the subgroups of patients' TMJs with and without OA and asymptomatic volunteers for degenerative changes of articular eminence) or Fischer's exact test (subgroups of patients' joints with and without clinical signs of OA for degenerative changes of condyle; subgroups of asymptomatic volunteers' joints and patients' TMJs without OA for degenerative changes of articular eminence). The reliability of MRI interpretation was tested for all subjects on the basis of two researchers' (a radiologist D. Z. and a dentist T. B.) inspection, which was conducted independently of each other and of the patient's clinical signs in TMJs, and it was evaluated by Cohen kappa index (κ=0.80-1.0). Cohen kappa index for matching of the clinical diagnosis of OA and definitive diagnosis based on a radiological finding was 0.72.

Results

OA was diagnosed in 35 (58.3%) of all TMJs, and it was present bilaterally in 5 patients (16.6%). Anterior DD was an additional finding which was determined in 13 patients (43.33%) whereas the other 17 patients (56.67%) had physiological disc position. Out of all patients with DD, only one had DD with reduction, while the others had DD without reduction.

The most frequent symptoms reported by the patients were pain (95%) and crepitation (80%) in TMJ. Average value of temporomandibular pain intensity rated on VAS was 6.56±2.03 (range 3.0-10.0). Average pain duration from the onset of pain until the examination within this study was 13.72±17.95 months (range 1-84 month). 18% of the patients had acute pain (duration ≤3 months), 38% had subacute pain (≥4 months ≤12 months) and 44% of the patients experienced chronic pain (>12 months). This symptomatology, particularly of pain, did not include numerous previous symptoms (pathological noise) which were not considered relevant by the patients and therefore, only the recent symptoms for which the patients sought help at our Department were included. There was a significant difference (t-test 3.549318 (df=48), p=0.00088) between active opening of patients (average 42.57±9.87 mm with range: 15-62 mm) and students (average 52.13±5.52 mm with range: 42-62 mm).

There were no degenerative changes of the condyle in TMJs of asymptomatic volunteers, including flattening of condylar head. Various degenerative changes of condyle in both subgroups of patients' joints (with and without clinical signs of OA) were found (table 1) with a statistically significant difference between them (Fischer's exact test, p=0.009). In 28% of osteoarthritic joints, flattening of condylar joint surfaces was observed (figures 1 and 2) and 17.4% of the joints were without clinical signs of OA. Moderate sclerosis of the condyle was found in 12% of patients' joints without OA. Moderate sclerosis was found in 11.4% of osteoarthritic patients' joints and in 22.9%, pronounced sclerosis was found. Osteophyte formations in were found in 8% of asymptomatic joints and osteophyte formations with subchondral cysts were found in 25.7% of patients' joints with OA.

Changes of the articular eminence were found in all subgroups of joints, including the asymptomatic volunteers (table 2). Moderate shape loss and severe sclerosation of the articular eminence were observed in two students' TMJs bilaterally. A comparison of the patients' and asymptomatic volunteers' joints showed a sta-

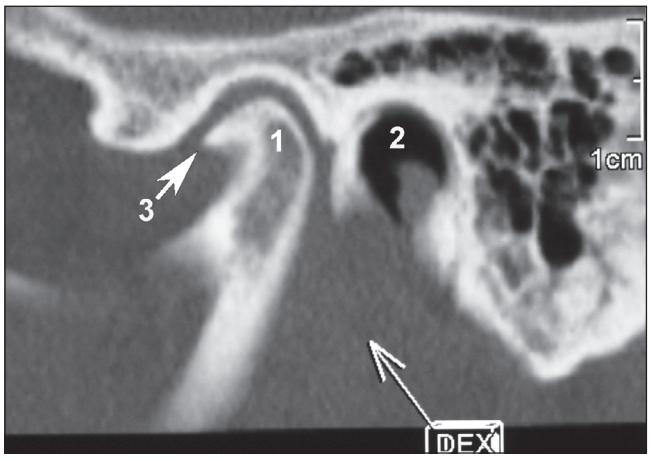
Table 1. **Comparison between the subgroups of patients' temporomandibular joints with and without OA diagnosis**
Tablica 1. **Usporedba između podgrupa temporomandibularnih zglobova bolesnika s i bez dijagnoze OA**

Condyle (number of joints)	No osteoarthritic signs	Deplaned shape	Moderate sclerosation	Pronounced sclerosation	Osteophyte and subchondral cyst	Total
Patients - without OA	13 (52.00%)	7 (28.00%)	3 (12.00%)		2 (8.00%)	25 (100%)
Patients - with OA	8 (22.86%)	6 (17.14%)	4 (11.43%)	8 (22.86%)	9 (25.71%)	35 (100%)

Table 2. **Comparison between the subgroups of patients' temporomandibular joints with and without OA diagnosis and the asymptomatic volunteers** (physiological joints without OA)
Tablica 2. **Usporedba između podgrupa temporomandibularnih zglobova bolesnika s i bez dijagnoze OA te asimptomatskih dobrovoljaca** (fiziološki zglobovi bez OA)

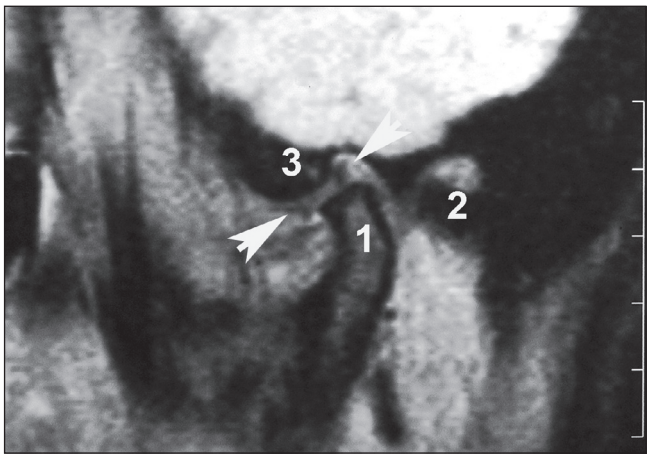
Articular tuberculum (number of joints)	No osteoarthritic signs	Moderate sclerosation	Pronounced sclerosation	Total
Patients - without OA	12 (48.0%)	10 (40.0%)	3 (12.0%)	25 (100%)
Patients - with OA	2 (5.7%)	18 (51.4%)	15 (42.9%)	35 (100%)
Asymptomatic volunteers	24 (60.0%)	12 (30.0%)	4 (10.0%)	40 (100%)

Figure 1. **Osteoarthritic TMJ in sagittal plane by CT of a 68-year-old female patient**
Slika 1. **Osteoartritički TMZ u sagitalnoj ravnini prikazan pomoću CT-a u 68-godišnje bolesnice**



1 - flattening with sclerosis of condylar joint surfaces
2 - external auditory meatus
3 - osteophyte formation

Figure 2. **Osteoarthritic TMJ in sagittal plane by MRI of a 54-year-old female patient**
Slika 2. **Osteoartritički TMZ u sagitalnoj ravnini prikazan pomoću MR-a u 54-godišnje bolesnice**



1 - deplaned condyle 2 - external auditory meatus
3 - sclerosis of the articular eminence
arrows - physiological position of articular disc

tistically significant difference (chi-square test 28.1716 (df=4), p<0.0001). Differences between the subgroups of asymptomatic volunteers' joints and patients' TMJs without OA were specially analyzed and they did not reveal any statistically significant data (Fisher's exact test, p= 0.8038). However, a comparison between the subgroups of patients' joints (patients' TMJs with and without OA) revealed a statistically significant difference (chi-square test 16.2122 (df=2), p=0.0003): pronounced shape loss and severe sclerosation of the articular eminence were found in 12% of joints without OA, and 42.9% of joints with OA.

Discussion

Osteoarthritis a major public-health issue and has been especially prominent in the recent decade which the World Health Organization (WHO) dedicated to musculoskeletal diseases. Symptomatology, clinical and radiological diagnostics as well as creating the most effective treatment methods and rehabilitation of other joints in the body have been researched more and given a lot of attention compared to the specialized field of the stomatognathic system and TMDs (21-24).

In the general sample, TMD patients are mostly women of reproductive age (according to Mafredini et al. (83.4%) between 20 and 40 years old (25). The average age is somewhat lower in patients with DD of TMJ and it is about 35 years (4,26). Although, in general, OA of TMJ is considered to be related to increase in age (3), it was only partially determined in our sample. Our study included somewhat older subjects (median age 53), but the age range was large, starting with adolescents.

In a study on the use of various treatment modalities of OA of TMJ, Machon et al. (27) examined patients of the same age (median age 52.8 years) and 76.25% of the patients' group were female. Campos et al. (9) retrospectively reviewed patients with degenerative changes of the TMJ and had a sample with mean age of 40.8 years, range of age between 15-76 and 86% females. In their retrospective study, Zhao et al. (14) showed that OA of TMJ is a common finding in individuals between 11 and 30 years of age: prevalence was 14.6% in a sample of 4883 patients, out of them, 68% of patients with OA were female. The results are limited by the dominant use of TMJ x-ray and panoramic radiography. Our study had 83% of female patients.

Long-lasting TMJ symptoms, as long as 20 years prior to seeking professional help, are related to general functioning of the stomatognathic system and to the fact that patients recognize certain symptoms, such as clicking in the TMJ, as those which require consultation and treatment (28,29). In our study, there were cases with up to 7 years from the onset of pain until the patient visited a dentist due to OA.

In their respective studies, Arslan et al. (4) and Sylvester et al. (7) collected MRIs of patients with DD and they found a significant correlation with accompanying arthritic changes. Although Rammlesberg (8) does not directly relate DD without reduction to osteoarthritic changes, Arslan et al. (4) found apparent significance (15.2% of joints), but they were also present in joints with DD with reduction (4.9%). Since the sample in our study was smaller and we were more focused on patients with clinical and radiological findings of OA, it can be argued that there is a connection to DD without reduction, but in our study, OA was also found in joints with physiological DD.

Similarly, Campos et al. (9) principally demonstrated the relationship of osteoarthritic TMJs with DD without reduction. In comparison with our study, Campos et al. (9) found absence of degenerative bone changes in 36% of joints, and osteophytes with or without erosions in 50% of joints, including 0.5% of joints additionally with subchondral cyst. In our study, 25.71% of joints had osteophytes with subchondral cyst formations. Absence of degenerative bone changes in TMJs without OA was 80% with including flattening of condyle, and in 88% with including moderate sclerosation of articular tuberculum.

In an MRI study of the correlation of osteoarthritic changes and DD of TMJs with mean 7 years of follow-up, Kurita et al. (5) found that after the initial examination, osteoarthritic changes predominantly occurred in joints with DD without reduction. In our study, patients with OA were collected from the total sample which also included patients with clinically and radiologically diagnosed DD. In our sample of patients, OA of TMJ was found in 43.33% of joints. However, during a follow-up period, Kurita et al. (6) concluded that further development of radiological signs of OA did not correspond to the state of resolved or reduced TMJ clinical symptoms and signs.

Bernhardt et al. (13) showed that in the epidemiological study by MRI, on the basis of several good definite criteria of functional disturbances addressed to TMJs, such as pain during palpation of the TMJs and at limitation of mouth opening less than 40 mm, OA changes were found in 25% of all subjects, unilaterally or bilaterally. However, Alkhader et al. (30) concluded that the value of MRI for the detection of TMJ osseous abnormalities is considered to be limited.

Brooks et al. (11) and Wiberg and Wänman (12) found high prevalence of radiographic signs of OA in asymptomatic TMJs in the case of 50 to 90%. Campos et al. (9) reported that flattening of the condyle is not related to degenerative bone changes; they came to that conclusion after examining the patients' sample with degenerative changes of TMJs. Our study shows that there is no statistically significant difference between changes of articular eminence between patients' TMJ without OA and non-patients' joints.

In the validation of MRI finding of OA it is possible to explain mild degenerative bone changes as false positive results (31). However, there is some limitation in using various radiological techniques - invasive and/or x-ray techniques are unacceptable for non-patient subjects. We may assume it is the reason why in 30% of joints of asymptomatic volunteers from our study moderate sclerosation was found.

Conclusion

In conclusion, OA of TMJ was associated with DD without reduction (in our study 43.33% of patients' joints had OA in comorbidity with DD without reduction), but OA may develop in joints with physiological disc position. In the patients' sample, 41.7% of joints were without OA diagnosis.

Absence of degenerative changes on articular tuberculum was established in 48% of joints and on con-

dyle in 52% of joints. In the group of healthy, asymptomatic volunteers only minimal deplaned condyle and/or articular eminence was found, which was considered physiological.

References

1. Manfredini D, Bucci MB, Montagna F, Guarda-Nardini L. Temporomandibular disorders assessment: medicolegal considerations in the evidence-based era. *J Oral Rehabil* 2011;38:101-19.

2. Durham J. Temporomandibular disorders (TMD): an overview. *Oral Surgery* 2008;1:60-8.

3. Tanaka E, Detamore MS, Mercuri LG. Degenerative disorders of the temporomandibular joint; etiology, diagnosis, and treatment. *J Dent Res* 2008;87:296-307.

4. Arslan A, Orhan K, Semra Paksoy C, Ucok O, Ozbek M, Dural S, Kanli A. MRI evaluation of the classification, frequency, and disc morphology of temporomandibular joint disc displacements: a multicenter retrospective study in a Turkish population. *Oral Radiol* 2009;25:14-21.

5. Kurita H, Uehara S, Sakai H, Kamata T, Kurashina K. Radiographic follow-up of diseased temporomandibular joints. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2005;100:427-32.

6. Kurita H, Uehara S, Yokochi M, Nakatsuka A, Kobayashi H, Kurashina K. A long-term follow-up study of radiographically evident degenerative changes in the temporomandibular joint with different conditions of disk displacement. *Int J Oral Maxillofac Surg* 2006;35:49-54.

7. Sylvester DC, Exss E, Marholz C, Millas R, Moncada G. Association between disk position and degenerative bone changes of the temporomandibular joints: an imaging study in subjects with TMD. *Cranio* 2011;29: 117-26.

8. Rammlesberg P. *Untersuchungen über Ätiologie, Diagnose und Therapie von Diskopathien des Kiefergelenkes.* Berlin: Quintessenz. 1998.

9. Campos MI, Campos PS, Cangussu MC, Guimarães RC, Line SR. Analysis of magnetic resonance imaging characteristics and pain in temporomandibular joints with and without degenerative changes of the condyle. *Int J Oral Maxillofac Surg* 2008;37:529-34.

10. Badel T, Marotti M, Keros J, Kern J, Krolo I. Magnetic Resonance Imaging Study on Temporomandibular Joint Morphology. *Coll Anthropol* 2009;33:455-60.

11. Brooks SL. Westesson P-L, Eriksson L, Hansson LG, Barsotti JB. Prevalence of osseous changes in the temporomandibular joint of asymptomatic persons without internal derangement. *Oral Surg Oral Med Pathol* 1992;73:122-6.

12. Wiberg B, Wänman A. Signs of osteoarhrosis of the temporomandibular joints in young patients. A clinical and radiographic study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998;86:158-64.

13. Bernhardt O, Biffar R, Kocher T, Meyer G. Prevalence and clinical signs of degenerative temporomandibular joint changes validated by magnetic resonance imaging in a non-patient group. *Ann Anat* 2007;189:342-6.

14. Zhao YP, Zhang ZY, Wu YT, Zhang WL, Ma XC. Investigation of the clinical and radiographic features of osteoarthrosis of the temporomandibular joints in adolescents and young adults. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;111:e27-34.

15. Bumann A, Lotzmann, U. *TMJ Disorders and Orofacial Pain - The Role of Dentistry in a Multidisciplinary Diagnostic Approach.* Thieme, Stuttgart-New York. 2002.

16. Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach R, Truelove EL, John MT, Schiffman E. Research diagnostic criteria for temporomandibular disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;107:844-60.

17. Badel T, Podoreški D, Marotti M., Kern J, Savić Pavičin I. Osteoarthritic temporomandibular joint changes validated by magnetic resonance imaging. *Clin Exp Rheumatol* 2009;27:738.

18. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: Review, criteria, examinations and specifications, critique. *J Craniomandib Disord Facial Oral Pain* 1992;6:301-355.

19. Badel T, Pandurić J, Marotti M, Kern J, Krolo I. Metrička analiza temporomandibularnog zgloba magnetskom rezonancijom u asimptomatskih ispitanika. *Acta Med Croat* 2008;62:455-60.

20. Williamson A, Hoggart B. Pain: a review of three commonly used pain rating scales. *J Clin Nurs* 2005;14:798-804.

21. Grazio S. Međunarodna klasifikacija funkcioniranja, neposobnosti i zdravlja (ICF) u najznačajnijim bolestima i stanjima reumatološke prakse. *Reumatizam* 2011;58:27-43.

22. Badel T, Savić Pavičin I, Krapac L, Podoreški D, Marotti M, Kern J. Bone mineral density in groups of patients with temporomandibular joint disorders. *Osteoporosis Int* 2011;22 (Supp 1):396-7.

23. Krapac L, Badel T. Disorder of temporomandibular joint - a rheumatological and physiatric approach. *Rad HAZU Medicinske znanosti* 2010;34:97-109.

24. Badel T, Pandurić J, Marotti M, Kocijan Lovko S, Krolo I. Inicijalna terapija osteoartritisa čeljusnoga zgloba. *Reumatizam* 2006;53:29-32.

25. Manfredini D, Piccotti F, Ferronato G, Guarda-Nardini L. Age peaks of different RDC/TMD diagnoses in a patients population. *J Dent* 2010;38:392-9.

26. Badel T. *Temporomandibularni poremećaji i stomatološka protetika.* Zagreb: Medicinska naklada. 2007.

27. Machon V, Hirjak D, Lukas J. Therapy of the osteoarthritis of the temporomandibular joint. *J Craniomaxillofac Surg* 2011;39:127-30.

28. Badel T, Kraljević S, Pandurić J, Marotti M. Preprosthetic therapy utilizing a temporary occlusal acrylic splint: A case report. *Quintessence Int* 2004;35:401-5.

29. Duan X, Junzheng WU, Mao Y, Wang H, Wang M. A retrospective study on the relationship between aging and tomographic findings in 174 patients with TMD. *Oral Radiol* 1999;15:9-17.

30. Alkhader M, Ohbayashi N, Tetsumura A, Nakamura S, Okochi K, Momin MA, Kurabayashi T. Diagnostic performance of magnetic resonance imaging for detecting osseous abnormalities of the temporomandibular joint and its correlation with cone beam computed tomography. *Dentomaxillofac Radiol* 2010;39:270-6.

31. von Lindern JJ, Niederhagen B, Bergé S, Conrad R, Reich RH. Magnetresonanztomographie versus Arthroskopie in der Diagnostik von Kiefergelenkerkrankungen - unter Berücksichtigung der schnellen EPI-FFE-Sequenzen. *Dtsch Zahnärztl Z* 2001;56:99-103.