SMGroup

Imaging for Temporomandibular Disorder

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INTRODUCTION

Temporomandibular Disorder **(TMD)** refers cumulatively to bone, joint, ligament and muscular dysfunction [1,2]. Multiple terminology of TMD reflects multiple attempts for its clinical and therapeutic approach [3-8]. Although very common [9,10] TMD has no uniform protocol for classification and staging [7,10-15] and at least three systems meet wide acceptance, namely the RDC/TMD system, the Helkimo scale and the Wilke's criteria [16-23], whilst many more are used individually. The clinical examination is the main tool for the diagnosis of craniofacial disorder. However, all of the proposals on classification, staging and clinical diagnosis of TMJ have shortcomings, as:

1) The subjectivity of symptoms reported by the patient. That's why in Helkimo & RDC / TMD scales symptoms are recorded separately from the clinical signs (Di anamnestic index in Helkimo and Axis II in RDC / TMD) [17,20, 22].

2) The objectivity in assessing of clinical signs by the examiner: intra-examiner reliability i.e. the same examiner who re-evaluates a patient, or inter-examiner reliability, when a patient is examined independently by more than one examiner vary considerably. Researchers of RDC / TMD have dealt particularly with this shortcoming [24-28].

3) Assessment of the mobility of the lower jaw, where Helkimo scale evaluates active opening. Active opening is known to be limited either by muscle contraction or by intra-articular obstacle,

but also by psychogenic factors (fear). For objective estimation of mandibular kinetics various devices or computer programs have occasionally been designed [29-32]. Differentiation between active and passive opening is considered diagnostic for mechanical obstacle and is clearly indicated in the index RDC / TMD [18].

4) The "recurrent" dislocation and TMJ hypermobility, which is certainly related to temporomandibular disorder, is provided only by the Helkimo index [33,34].

5) "Disk anchorage" is not recognized by any of the known clinical classifications [35,36]. It has to be stressed however, that this condition has not been generally accepted.

6) The importance of occlusion that is not assessed at all in RDC / TMD although at Helkimo scale employs 1/3 of the physical examination [21].

7) Co-existence of more than one pathologies in many patients with TMD cannot be recorded in any of the existing clinical systems. Myalgias developing after anterior disc displacement or the co-existence of chronic, irreducible displacement with osteoarthritis are frequent syndromic pathologies. RDC-TMD system classifies patients into only one category "ignoring" other symptoms and Helkimo scale calibrates severity numerically, without giving specific information on each condition.

Only Wilkes criteria [23] and class IIb (disc displacement without reduction, with limited mouth opening) of the RDC / TMD incorporate imaging, although in practice, but also in the literature, imaging of TMJ is widespread, albeit not always successfully. Evolution in the medical image could not let such a very common disease unaffected, even though most of clinical examination protocols are designed to minimize the need for imaging in TMD [18,21,23,37] So the literature for ultrasound for TMJ increased by 100% in the years 2000-2004 over the previous quinquennium and 50% more in the next one [38]. Similar, but more durable, was the increment for MRI. The vast majority of studies on the reliability of imaging for TMD are about MRI and sometimes arthroscopy confirms either finding [39]. Accordingly, the clinical protocols assessed by MRI findings, or other imaging modalities, include Wilkes and Helkimo scales [39,40], but the most systematic studies concern the RDC-TMD [41-44]. Of course there are studies comparing TMJ imaging to clinical diagnoses made by unknown protocols [45] or studies in which various imaging methods are compared between them, without clinical confirmation [42,46].

ORTHOPANTOMOGRAM

The Orthopantomogram **(OPG)** is used for a "first look" at TMD as familiar, relatively low cost and radiation imaging, which by digitizing the OPG became even less (estimated near 12-13 mGy), and enabling to assess the condyle in open and closed mouth[47]. But already in 1997, the American Academy of Oral & Maxillofacial Radiology had noted the low predictive value of OPG in TMD. Specifically, only large osteoarthritic lesions, and only on the lateral half of the condyle are adequately depicted in OPG [48]. Experimental studies have shown the strong correlation of the image obtained on the OPG with the movement of the beam and the head position [49].

Nevertheless, studies comparing OPG with other images continued for long after 1997, not only on its sensitivity of osteoarthrosis but also of the internal derangement [47,50].

Compared with the traditional static TMJ projections in showing osteoarthritic lesions, OPG's sensitivity is estimated on 70% [51,52]. Well-designed studies of the value of OPG in osteoarthritis give it a sensitivity of 60-70% and, most importantly, very low negative predictive value meaning that the absence of osteoarthritic lesions cannot exclude the disease [53]. This is probably the biggest drawback of OPG in diagnosis of TMD.

Some authors believe that OPG can serve only for early diagnosis of TMJ involvement in screening patients already diagnosed with arthritis [55], while others recognize CBCT as standard, assigning a relatively low value for OPG as a screening tool [56,57]. Also OPG contributes only a little in synovial chondromatosis where CT and MRI are considered the examinations of choice at all stages of the disease [58,59]. Finally, precarious are the conclusions in studying condylar size and shape in situations as the unilateral condylar hyperplasia or hypoplasia [60]. In conclusion,the literature shows that OPG has little diagnostic value even for radiopaque lesions of TMJ. Moreover, the excessive use of OPG in diagnostics of TMD, may lead to false conclusions and incorrect diagnoses as usually happens for the evaluation of joint space, which proved to be completely invalid in OPG [49]. The only definite diagnostic contribution of OPG in TMD is the confirmation -in open mouth shots - of recurrent dislocation and hypermobility (Figure 1), which is a strong predisposing factor for TMD without being pathology itself [61].

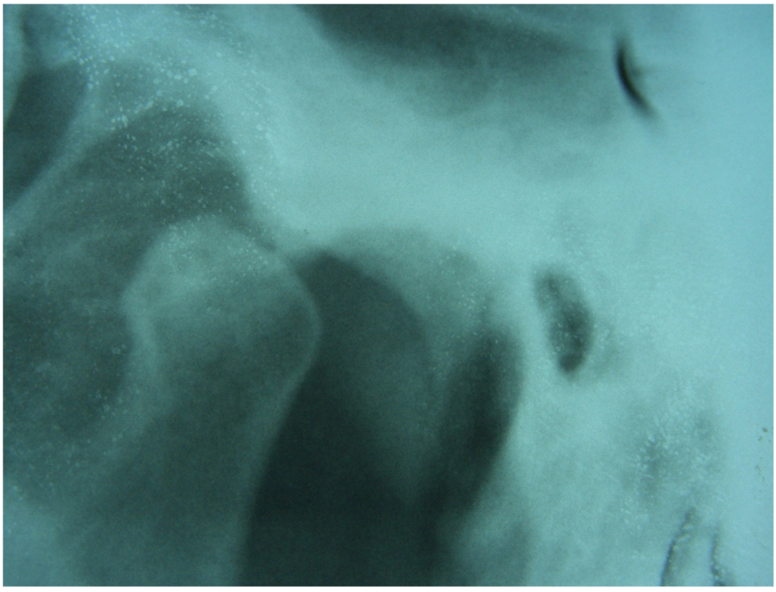

Figure 1: Left condyle particularity from an OPG showing subluxation and changes in shape of the condyle.

PLAIN (STATIC) VIEWS AND ARTHROGRAPHY

Many of the above “failures” of OPG are due to movement of the beam, but plain (static) radiographs of the joint have the disadvantage of superimposing elements [47]. Therefore it is said that a basic study of the joint with plain radiographs should include at least two projections, perpendicular to each other [47,48]. Studying TMJ with plain radiographs must: a) show as many surfaces as possible with as fewer superimpositions and deformations, b)display, if possible, both joints and, most importantly, c) be accurate and reproducible for comparison whenever needed [62].

Lateral Views

Lateral projections depict condyles in the sagittal plane, so that condylar poles and condyles overlap each other, therefore it is necessary for the operator to angulate the beam appropriately.

In transcranial projection the beam is placed over the external ear canal and is directed to the articular surface of the opposite condyle [48,63]. In transcranial view, also known as Schuller, the condyle resembles a lot with that of OPG so that only fractures with severe displacement and only large osteoarthritic lesions of the lateral pole can be seen.

Anteroposterior Views

The common problem with anteroposterior projections is the interference of the anterior articular tubercle and mastoid process on the condylar silhouette. This can be handled either by shooting in full mouth opening, although this is not always feasible in patients with TMD, or by slight tilting of the beam in a cephalic or caudal direction to “bypass” the mastoid proccess. These handlings display not just the articular surface of the condyle but slightly behind or slightly ahead of it, reducing sensitivity for osteoarthritis by approximately 50% [64]. Their advantage, however, is depicting both condyles simultaneously in condylar fractures with small displacement, when the lateral pterygoid shifts the fragment medially, making it clearly visible [47,48,63].

In Towne’s and reverse Towne’s projection, beam is positioned near the frontonasal angle and the receptor (film or digital medium) in the occipito-cervical area, or vice versa. Towne’s, can display both condyles simultaneously and highlights the styloid processes and condylar fractures [64,65].

Tomography and Arthrography

Tomography, as in OPG, uses a moving x-ray beam and moving receptor and was used widely for imaging of other joints, before digital technology [66]. The disadvantage of tomography is that image, above or below the plane of rotation of the machine appears blurred [67]. The movement of the tomographic apparatus may be complex or linear, which affects the diagnostic value but also the cost of examination [68]. Tomography is believed to have greater diagnostic value than the static projections in displaying bone abnormalities, as it avoids superimposing, especially with complex movement of the tomographic apparatus [48,69-73]. Disc is not visible in tomography. Attempts to localize disc indirectly, with measurements of joint space, lasted almost a decade. The results were not as expected, so the relation of TMD with dental occlusion, which until then was considered affecting condylar position, reconsidered, while prevailed intra-articular injection of contrast medium for depiction of the disc, known as arthrography, or, when a tomography was applied, artho-tomography [72,74-79].

In artrography a contrast medium is injected in the upper or lower joint space and small quantity of air may also be injected, producing the dual-contrast arthrography [80-83]. The whole process can be captured on video, improving the diagnostic value of arthrography [84]. Technical improvements, cumulatively, gave arthrography enough reliability, that even after the introduction of CT and MRI some considered it superior in demonstrating osteoarthritic lesions and disc adhesions or perforations [85,86]. At the same time other comparisons between arthrography and MRI credited the first false positive findings [87].

Correlations however, in large series of patients, between clinical and arthrographic diagnoses gave no clear conclusions about the indications and value of arthrography in TMD [84,88,89]. So, as it is an invasive technique, and exposes patients, especially video, seriously to radiation, the American Academy of Oral & Maxillofacial Radiology at the position paper issued in 1997 does not give clear guide for its usefulness [48].

ULTRASOUND

Ultrasound's first application in TMD was in 1975 [90], but the first publications considered systematic studies, made in early 1990's [91]. Meanwhile, the "minimal invasiveness" in TMD therapeutics was developed, necessitating reproducible, harmless and cheap displaying of results and, moreover, real-time disc movements or imaging guidance for operating handlings [92,93]. Ultrasound provides information about both the position of the disc and the existence of intraarticular fluid [93,94] .

In ultrasound a high-frequency sensor (7.5 to 20 MHz) is placed on the pre-auricular area, perpendicular to the zygomatic arch and parallel to the mandibular ramus or, according to others, on the line connecting the tragus of the ear with ipsilateral nasal alar, known as Camper line, and rotated to achieve the best display [94-96]. By opening or closing patient's mouth, static or dynamic images are gained. The cortical bone of the condylar head, the fossa and the surface of the eminence reflect fully the ultrasound waves (hyperechoic tissues) and appear white on the ultrasound images, while the spongy marrow reflects in a lesser degree, appearing black. The connective tissues as joint capsule, the retrodiscal ligament, and muscles reflect sound waves moderately (isoechoic tissues) and heterogeneously appear gray. The "empty" spaces (upper and lower articular space-hypoechoic tissues) appear black and are most evident with presence of effusions (fluid). The articular disc is composed of dense fibro-cartilaginous tissue and typically appears as a thin area of low reflection of ultrasonic waves (black), surrounded by a white "halo" [96]. The position of the disc in the open mouth is considered normal when located between the anterior articular tubercle and condylar head [96,97], but the difficulty in identifying it led some to indirect calculations using parameters such as the condyle-fossa distance [98,99].

In literature, among hundreds of papers, there are large series studies [100] or systematic reviews [101] encapsulating conclusions of other studies, in the form of averages for parameters such as sensitivity, specificity and accuracy of ultrasound in anterior disc displacement. These studies provide inconsistent and often conflicting results on the diagnostic value of ultrasound for TMD. This is due to the fact that ultrasound depends largely on the examiner's experience, to the frequency of the transducer, the technology of equipment and examination protocols, that have not been standardized yet [94,95,102,103]. Ultrasound's greater sensitivity is in detecting joint effusion, a sign of inflammation in to the joint, in situations such as systematic arthritides (psoriatic, reumatoid), episodes of pain in osteoarthritis but also in traumatic arthralgia due to bruxism [95].

Ultrasound's sensitivity in disc displacement ranges between 41% in the first publications [104], to 90% or more in most recent ones [105]. A review credits an average of 80% to this ascending proccess [99]. It is striking that at least in one case, the same center, by sequential publications, records an increase of ultrasound's sensitivity and specificity, as experience and equipment technology improves [104,106,107]. Nowadays, sensitivity and specificity of ultrasound for disc displacement, in the hands of experienced examiners, seems to approach that of MRI, although there is a difficulty in locating the disc, not existing in large joins [108].

Muscular hypertrophy or contraction was studied in ultrasound by orthodontists and others [109-112]. The conclusion from these studies is that muscular activity may be detectable by ultrasound, but the norms (protocols) for definite diagnosis are not released yet. In osteoarthritic defects ultrasound recorded unsatisfactory rates [113]. In a systematic review, the accuracy and specificity of ultrasound ranges greatly (67-95 and 20-100% respectively), not allowing useful conclusions on its ability to detect osteoarthritic lesions [100]. Conclusively, the ultrasound is evolving technology, providing an economical and reproducible imaging for TMJ, which, in hands of a properly trained clinician, promises to complement the clinical diagnosis and track effectively therapeutic maneuvers and results.

CT AND CBCT

Unlike ultrasound, computed tomography is expensive and exposes patient to radiation. In maxillofacial radiology the Cone-Beam Tomography has prevailed **(CBCT)** against the CT used in imaging the rest of the body and is referred to as "medical CT» «spiral CT», «multi-slice CT» etc. CBCT is proved to expose patient in about 20% lower radiation than spiral CT, although this does not mean that one can repeat it often, or apply it to children or young people without strong evidence [113-116].

The CBCT came into clinical use in the late '90's, but used widely during the next decade, so the relevant publications, concerning the CBCT in orthodontics only, today surpass 600 [117,118]. What differentiates it is the collection of data from a single rotation of beam, analyzing and recomposing it later, with specific software. So imaging of soft tissue is poor, due to insufficient data. Thus, the main indication of CBCT for TMJ is imaging of hard tissues, and not disc [114,119,120]. Nevertheless some studies argue that CBCT may alter the clinical diagnosis or treatment of the TMD, whatever it is [54].

Techniques for indirect determination of disc position in CBCT employed many researchers who worked on the hypotheses that disc dislocation may change the position or shape of the condyle [121-134]. Studies on the condylar position dealt with either transverse or sagittal views, and based on the supposals that the condyle is placed posteriorly on disc dislocation, or even that its axis is tilted [124-127]. Heterogeneity of their results increases by the fact that the referral diagnosis "disc dislocation" 'wasn't placed under uniform protocol, in many "disclocated" cases the condyle was found in "normal" position, whereas, in many asymptomatic patients the condyle was positioned posteriorly [126,127]. The change in shape of the condyle appears to be better documented than position change, although there are no pathognomonic changes strongly associated with the diagnosis of disc dislocation [128-133].

CBCT is probably susceptible to further technical improvements. For example CBCT arthtrography, which has been widely used by orthopedists, could give information on the location of the disk that cannot be collected with the normal use of CBCT [59,135,136]. Also the technology of fusion of the images, already applied in PET-SCAN and available as separate software, is likely to provide additional capabilities to CBCT in the future [137].

In conclusion, the CBCT is nowadays indicated for joints suspected of osteoarthritis, where its sensitivity is approximately 0.75, specificity close to 100% , positive predictive value 1,0 and the negative 0.75 or in ankylosis but without demonstrating soft tissues [85]. It clearly surpasses static views and OPG (Figure 2), but not the spiral CT and, therefore, its actual contribution in TMD diagnostics is relatively low [138,139].

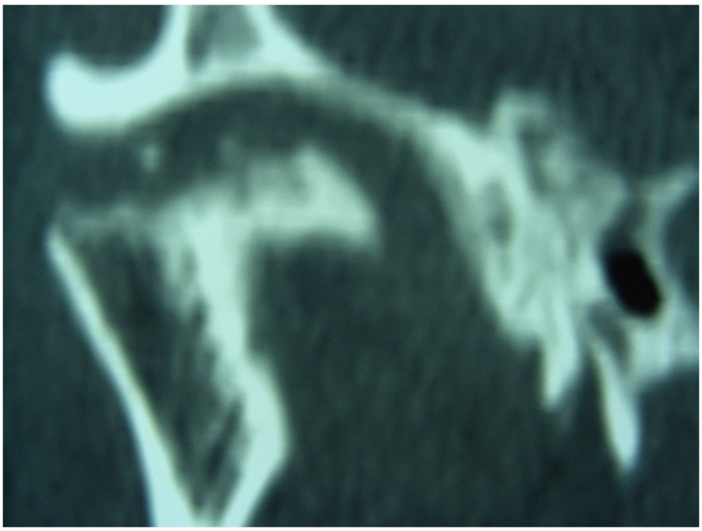

Figure 2: CBCT showing severe osteoathritic lesions of the right condyle.

MRI AND ITS VARIANTS

Although expensive and contra-indicated in patients with metal inserts and claustrophobia, MRI replaced tomography and arthrography gradually within 10 years as non-invasive and radiation free exam, in a dissemination needing rationalization of its costs and benefits. MRI discerns more elements of the TMJ and surrounding tissues from other imaging. It is repeatedly written and said that "MRI is the golden standard for diagnosis of TMD" but one has to take into account concepts such as sensitivity, specificity, positive and negative predictive value when accessing a diagnostic modality.

It has been noted that the MRI may indicate problems in asymptomatic patients [140,141]. False positive (but also negative) findings increase, decreasing MRI's reliability, when the joint is not displayed in sagittal sections, at open mouth position and when the posterior band, instead of the intermediate zone is assessed [37,142]. Therefore, no matter how many elements MRI discerns, there are two basic requirements crediting clinical value to MRI: a) that must be ordered for specific clinical indications and b) the interpretation of findings should be done under protocols [42,43,143]. By doing so, MRI may affect significantly both, diagnosis and the treatment plan of TMD [145].

Two sequences are used in the TMJ study with MRI: T1 and T2 Weighted Image **(T1WI - T2WI).** Their difference, due to perpendicular magnetisation vectors, could be summarized in that the first illustrates the fluids dark, while the second light. The majority of MRI ordered for TMJ is T1WI, and projections are mainly sagittal.

MRI's main indication in TMD is confirmation of Anterior Disc Displacement **(ADD).** Incipient displacement with reduction, which is diagnosed in closed-mouth position, has been-and still is-a matter of dispute. According to one approach the diagnosis is made when the posterior band is located anteriorly to the condylar top (superior aspect) in sagittal sections [37,145]. According to the other, the dark (low signal) intermediate zone is used in the same way instead of the posterior band [146]. Thus, the first approach considers fewer cases as pathologic. Practically, this difference affects treatment (and thus MRI's efficacy), as some recommend intraarticular lavage when the imaging confirms clinical diagnosis of ADD with reduction, to "unstuck" the disk [144].

Established ADD, however, is fairly well recognized in MRI, as shown in one of the first large studies with relatively high level of reliability, which used four independent examiners [147]. The sequence most used to estimate disc position is T1WI although there are opposite positions [45]. The usual view is the sagittal, but frontal is of diagnostic value not yet calibrated fully, and should be combined to sagittal views [43]. Displacement of the disc in frontal view takes as landmarks the lateral and medial poles of the condyle. A rough definition of displacement in frontal view is that "lateral disc displacement" is the presence of the disc over the lateral pole, whereas "medial displacement", is its presence above the medial pole [146]. One cannot calculate precisely the accuracy of MRI in ADD but sensitivity is estimated to reach 0,7 specificity about 0,6, positive predictive value 0,65 and considerably higher negative predictive value [37,85,148].

The presence of fluid in the joint spaces (effusion) is, as said, indirect evidence of joint inflammation concerning many TMJ pathologies [143]. The intra-articular fluid is best seen in T2WI than in T1, while intravenous administration of "paramagnetic medium" (contrast enhanced MRI) has not proven to increase the sensitivity of MRI in detection of effusion.

In literature enough discussion has developed on the ability of MRI to demonstrate adhesions or perforations of disc [39,148-150]. Adhesions are thought to make ADD permanent, "stucking" the disc in an anterior position into the fossa [35,36]. Therefore, the presence of adhesions is an indication for TMJ lavage and this ads value to MRI in the therapeutic level. Disc perforations however have no great practical importance, except confirming the progressive disc degeneration. Both entities are not related, in general, to a specific stage or severity of TMD, but have been correlated to contrast enhanced MRI. In particular, intravenous administration of the paramagnetic substance demonstrates adhesions but not perforations, since the presence of the latter ascertained primarily indirectly, by the presence of liquid in both synovial spaces. In contrast, the intra-articular injection of paramagnetic substance at the upper articular space highlights both adhesions and perforations of the disc, because, when performed lege-artis, the contrast medium is not displayed in both spaces, if no perforation exists [151]. The technique is known as Mr Arthrography **(MRAr).** MRAr has been implemented by orthopedics for the study of many joints, mainly shoulder and hip [152]. But for TMJ had not spread particularly, perhaps because it's diagnostic value has little difference over conventional MRI, outweighed by its disadvantage of invasiveness [151,153,154].

As medical imaging is rapidly developing, today's status may change soon. The strength of the magnetic fields produced from MRI machines is believed to play an important role in TMJ imaging [155]. The same is supported for other specialized techniques not covered by this chapter [156]. Perhaps an important future evolution of imaging may come from the technology of image fusion [157]. Also, video reconstruction of images from MRI, a relatively simple process **(Video)**, or a new development, the actual MRI video recording, may give new perspective to the study of TMD [158,159]. In conclusion, MRI is the most "comprehensive" TMJ imaging, but often its findings are overestimated. Also it is expensive and therefore not easily reproducible examination, with low performance in the diagnosis of arthritides. Rational use of the MRI presupposes that clinical examination leaves considerable doubt on the diagnosis and the user of MRI is aware of all the possibilities and variations of MRI offered by technology.

SOCIO-ECONOMIC ASPECTS AND CONCLUSIONS

It has been written, that "diagnostic radiology is part of an objective process for the effective and adequate treatment of the patient" [144]. In this context, as mentioned before, the TMJ imaging is to be ordered when it is effective in 6 levels: [37,144]

1. Technically, imaging is valid only when its quality makes it readable

2. Diagnostically, the parameters: accuracy, sensitivity, specificity, positive and negative predictive value and examiner performance should be validated

3. Clinically, imaging is of value if it can change diagnosis or diagnostic thinking

4. At the treatment level, imaging should be capable to change the treatment plan

5. Patient outcome efficacy describes the value of an imaging in patient's follow up

6. Social efficacy balances the cost against the benefit in socio-economic terms.

Indeed, a clinician almost never takes into account the above six points before ordering a display. In the position paper of 1997, the American Academy of Oral & Maxillofacial Radiology addresses exactly this problem, and lists, to raise awareness of the clinician, a table incorporating indications and cost for any imaging for TMD [48]. Since 1997 many things have changed in the imaging technology. But unnecessary images for TMJ are still ordered today, which makes sense, because the medical imaging evolves, promising more than what an examiner is able to gain from it. Recession of indicators of public health systems and social insurances worldwide, tasks clinicians to sharpen their diagnostic capacity and to be limited to more targeted and effective choices for imaging, taking into account as many of the 6 criteria stated above.

Despite their shortcomings, the clinical classification schemes and staging of TMD, particularly the RDC/TMD, cover most of the needs of clinicians. Imaging should be used only when there is a significant differential diagnostic dilemma or substantial likelihood to change a diagnosis or treatment. Ultrasound, which has the smallest biological and socio-economic costs, could possibly increase its advantages, MRI, at present, answers to most diagnostic queries in TMD, the CBCT is to be ordered only where the TMD is attributed to bone lesions, and plain radiographs and OPG should not be used at all in temporomandibular disorder.

Video 1: Video reconstruction from T1WI MRI of a left TMJ showing an anterior disc displacement with reduction.

References

1. Griffiths RH. Report of the President's conference on the examination, diagnosis and management of temporomandibular disorders. J Am Dent Assoc. 1983; 106: 75-79.

2. McNamara JA Jr, Seligman DA, Okeson JP. Occlusion, Orthodontic treatment, and temporomandibular disorders: a review. J Orofac Pain. 1995; 9: 73-90.

3. Agerberg G, Carlsson GE. Symptoms of functional disturbances of the masticatory system. A comparison of frequencies in a population sample and in a group of patients. Acta Odontol Scand. 1975; 33: 183-190.

4. Costen JB. Neuralgia and ear symptoms associated with disturbed function of the temporomandibular joint. JAMA. 1936; 107:252-257

5. SCHWARTZ LL. Pain associated with the temporomandibular joint. J Am Dent Assoc. 1955; 51: 394-397.

6. Laskin DM. Etiology of the pain-dysfunction syndrome. J Am Dent Assoc. 1969; 79: 147-153.

7. Mohl ND, Dixon DC. Current status of diagnostic procedures for temporomandibular disorders. J Am Dent Assoc. 1994; 125: 56-64.

8. McNeill C. Craniomandibular (TMJ) disorders--the state of the art. Part II: accepted diagnostic and treatment modalities. J Prosthet Dent. 1983; 49: 393-397.

9. Wigdorowicz-Makowerowa N, Grodzki C, Panek H, Máslanka T, Plonka K. Epidemiologic studies on prevalence and etiology of functional disturbances of the masticatory system. J Prosthet Dent. 1979; 41: 76-82.

10. Ingervall B, Mohlin B, Thilander B. Prevalence of symptoms of functional disturbances of the masticatory system in Swedish men. J Oral Rehabil. 1980; 7: 185-197.

11. Dimitroulis G1. Temporomandibular disorders: a clinical update. BMJ. 1998; 317: 190-194.

12. Ageberg G, Carlsson CE. Functional disorders of the masticatory system II. Distribution of systems according to age and sex judged from investigation by questionnaire. Acta Odontol Scand. 1973;31:335-347.

13. Helms CA, Doyle GW, Orwig D, McNeill C, Kaban L. Staging of internal derangements of the TMJ with magnetic resonance imaging: preliminary observations. J Craniomandib Disord. 1989; 3: 93-99.

14. Fricton JR, Schiffman EL. Reliability of a craniomandibular index. J Dent Res. 1986; 65: 1359-1364.

15. Fricton JR, Schiffman EL. The craniomandibular index: validity. J Prosthet Dent. 1987; 58: 222-228.

16. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. J Craniomandib Disord. 1992; 6: 301-355.

17. Helkimo M. Studies on function and dysfunction of the masticatory system. 3. Analyses of anamnestic and clinical recordings of dysfunction with the aid of indices. Sven Tandlak Tidskr. 1974; 67: 165-181.

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

19. Truelove EL, Sommers EE, LeResche L, Dworkin SF, Von Korff M. Clinical diagnostic criteria for TMD. New classification permits multiple diagnoses. J Am Dent Assoc. 1992; 123: 47-54.

20. Dworkin SF, Huggins KH, Wilson L, Mancl L, Turner J, et al. A randomized clinical trial using research diagnostic criteria for temporomandibular disorders-axis II to target clinic cases for a tailored self-care TMD treatment program.J Orofac Pain. 2002; 16: 48-63

21. Helkimo M. Studies on function and dysfunction of the masticatory system. II. Index for anamnestic and clinical dysfunction and occlusal state. Sven Tandlak Tidskr. 1974; 67: 101-121.

22. Dworkin SF, Sherman J, Mancl L, Ohrbach R, LeResche L, et al. Reliability, validity, and clinical utility of the research diagnostic criteria for Temporomandibular Disorders Axis II Scales: depression, non-specific physical symptoms, and graded chronic pain. J Orofac Pain. 2002; 16: 207-220.

23. Wilkes CH. Internal derangements of the temporomandibular joint. Pathological variations. Arch Otolaryngol Head Neck Surg. 1989; 115: 469-477.

24. Goulet JP, Clark GT, Flack VF, Liu C. The reproducibility of muscle and joint tenderness detection methods and maximum mandibular movement measurement for the temporomandibular system. J Orofac Pain. 1998; 12:17-26.

25. List T, John MT, Dworkin SF, Svensson P. Recalibration improves inter-examiner reliability of TMD examination. Acta Odontol Scand. 2006; 64: 146-152.

26. Nilsson IM, List T, Drangsholt M. The reliability and validity of self-reported temporomandibular disorder pain in adolescents. J Orofac Pain. 2006; 20: 138-144.

27. Dworkin SF, LeResche L, DeRouen T, Von Korff M. Assessing clinical signs of temporomandibular disorders: reliability of clinical examiners. J Prosthet Dent. 1990; 63: 574-579.

28. Schmitter M, Ohlmann B, John MT, Hirsch C, Rammelsberg P. Research diagnostic criteria for temporomandibular disorders: a calibration and reliability study. Cranio. 2005; 23: 212-218.

29. Bernhardt O, Schiffman EL, Look JO. Reliability and validity of a new fingertip-shaped pressure algometer for assessing pressure pain thresholds in the temporomandibular joint and masticatory muscles. J Orofac Pain. 2007; 21: 29-38.

30. Cacho A, Martin C. Kinesiographic and sonographic changes in young Class II patients treated with functional appliances. Am J Orthod Dentofacial Orthop. 2007; 131: 196-201.

31. Radke JC, Ketcham R, Glassman B, Kull R. Artificial neural network learns to differentiate normal TMJs and nonreducing displaced disks after training on incisor-point chewing movements. Cranio. 2003; 21:259-64.

32. Gallo LM. Modeling of temporomandibular joint function using MRI and jaw-tracking technologies--mechanics. Cells Tissues Organs. 2005; 180: 54-68.

33. List T, John MT, Dworkin SF, Svensson P. Recalibration improves inter-examiner reliability of TMD examination. Acta Odontol Scand. 2006; 64: 146-152.

34. Nilsson IM, List T, Drangsholt M. The reliability and validity of self-reported temporomandibular disorder pain in adolescents. J Orofac Pain. 2006; 20: 138-144.

35. Kaneyama K, Segami N, Shin-Ichi T, Fujimura K, Sato J. Anchored disc phenomenon with a normally positioned disc in the temporomandibular joint: characteristics and behaviour. Br J Oral Maxillofac Surg. 2007; 45: 279-283.

36. Nitzan DW, Goldfarb A, Gati I, Kohen R. Changes in the reducing power of synovial fluid from temporomandibular joints with “anchored disc phenomenon”. J Oral Maxillofac Surg. 2002; 60: 735-740.

37. Petersson A. What you can and cannot see in TMJ imaging--an overview related to the RDC/TMD diagnostic system. J Oral Rehabil. 2010; 37: 771-778.

38. Lewis EL, Dolwick MF, Abramowicz S, Reeder SL. Contemporary imaging of the temporomandibular joint. Dent Clin North Am. 2008; 52: 875-890.

39. Millon-Cruz A, Martín-Granizo R, Encinas A, Berguer A. Relationship between intra-articular adhesions and disc position in temporomandibular joints: Magnetic resonance and arthroscopic findings and clinical results. J Craniomaxillofac Surg. 2015;43: 497-502.

40. Witulski S, Vogl TJ, Rehart S, Ottl P. Evaluation of the TMJ by means of Clinical TMD Examination and MRI Diagnostics in Patients with Rheumatoid Arthritis. Biomed Res Int. 2014; 2014: 328560.

41. Hellén-Halme K, Hollender L, Janda M, Petersson A. Web-based calibration of observers using MRI of the temporomandibular joint. Dentomaxillofac Radiol. 2012; 41: 656-661.

42. M, Hollender L, Anderson Q, Kartha K, Ohrbach R, Truelove EL, et al. 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: 844–860

43. Limchaichana N, Petersson A, Rohlin M. The efficacy of magnetic resonance imaging in the diagnosis of degenerative and inflammatory temporomandibular joint disorders: a systematic literature review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006; 102: 521–536

44. Koh KJ, List T, Petersson A, Rohlin M. Relationship between clinical and magnetic resonance imaging diagnoses and findings in degenerative and inflammatory temporomandibular joint diseases: a systematic literature review. J Orofac Pain. 2009; 23: 123–139

45. Chiba M, Kumagai M, Echigo S. Association between high signal intensity in the posterior disc attachment seen on T2 weighted fat-suppressed images and temporomandibular joint pain. Dentomaxillofac Radiol. 2007; 36: 187-191.

46. Geiger D, Bae WC, Statum S, Du J, Chung CB. Quantitative 3D ultrashort time-to-echo (UTE) MRI and micro-CT (Î¼CT) evaluation of the temporomandibular joint (TMJ) condylar morphology. Skeletal Radiol. 2014; 43: 19-25.

47. Venetis G, Beketova A, Dimitrakopoulos I, Koidis P. A review of the imaging modalities available for TMD diagnosis. Balkan J Stomatol. 2010; 14: 52-58.

48. Brooks SL, Brand JW, Gibbs SJ, Hollender L, Lurie AG. Imaging of the temporomandibular joint: a position paper of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1997; 83: 609-618.

49. Ruf S, Pancherz H. Is orthopantomography reliable for TMJ diagnosis? An experimental study on a dry skull. J Orofac Pain. 1995; 9: 365-374.

50. Ahn SJ, Kim TW, Lee DY, Nahm DS. Evaluation of internal derangement of the temporomandibular joint by panoramic radiographs compared with magnetic resonance imaging. Am J Orthod Dentofacial Orthop. 2006; 129: 479-485.

51. Ludlow JB, Davies KL, Tyndall DA. Temporomandibular joint imaging: a comparative study of diagnostic accuracy for the detection of bone change with biplanar multidirectional tomography and panoramic images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1995; 80: 735-43.

52. Habets LL, Bezuur JN, Jimenez Lopez V, Hansson TL. The OPG: an aid in TMJ diagnostics. III. a comparison between lateral tomography and dental rotational panoramic radiography (Orthopantomography). J Oral Rehabil.1989;16:401-406.

53. Dahlström L, Lindvall AM. Assessment of temporomandibular joint disease by panoramic radiography: reliability and validity in relation to tomography. Dentomaxillofac Radiol. 1996; 25: 197-201.

54. De Boer EWJ, Dijkstra PU, Stegenga B, de Bont LG, Spijkervet FK. Value of cone-beam computed tomography in the process of diagnosis and management of disorders of the temporomandibular joint. Br J OralMaxillofac Surg. 2014; 52:241-46.

55. Twilt M, Mobers SM, Arends LR, ten Cate R, van Suijlekom-Smit L. Temporomandibular involvement in juvenile idiopathic arthritis. J Rheumatol. 2004; 31: 1418-1422.

56. Winocur E, Reiter S, Krichmer M, Kaffe I. Classifying degenerative joint disease by the RDC/TMD and by panoramic imaging: a retrospective analysis. J Oral Rehabil. 2010; 37: 171-177.

57. Shetty US, Burde KN, Naikmasur VG, Sattur AP. Assessment of condylar changes in patients with temporomandibular joint pain using digital volumetric tomography. Radiol Res Pract. 2014; 2014: 106-059.

58. Lim SW, Jeon SJ, Choi SS, Choi KH. Synovial chondromatosis in the temporomandibular joint: a case with typical imaging features and pathological findings. Br J Radiol. 2011; 84: 213-216.

59. Matsumoto K, Sato T, Iwanari S, Kameoka S, Oki H. The use of arthrography in the diagnosis of temporomandibular joint synovial chondromatosis. Dentomaxillofac Radiol. 2013; 42: 1538-8284.

60. Schmitter M, Gabbert O, Ohlmann B, Hassel A, Wolff D. Assessment of the reliability and validity of panoramic imaging for assessment of mandibular condyle morphology using both MRI and clinical examination as the gold standard. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006; 102: 220-224.

61. Ögren M, Fältmars C, Lund B, Holmlund A. Hypermobility and trauma as etiologic factors in patients with disc derangements of the temporomandibular joint. Int J Oral Maxillofac Surg. 2012; 41: 1046-1050.

62. Madsen B. Normal variations in anatomy, condylar movements, and arthrosis frequency of the temporomandibular joints. Acta Radiol Diagn (Stockh). 1966; 4: 273-288.

63. Roberts D, Pettigrew J, Ram C, Joseph PM. Radiologic techniques used to evaluate the temporomandibular joint; I. Conventional methods. Anesth Prog. 1984; 31: 197-206.

64. Mazzetto MO, Andrade KM, Magri LV, Rodrigues CA, Watanabe PC. Anterior and medial angulations of the styloid process in subjects with TMD: clinical and radiographic findings. Braz Dent J. 2013; 24: 80-84.

65. Whaites E. The Temporomandibular Joint. In: Whaites E, editor. Essentials of dental radiography and radiology. Toronto: Churchille Livingstone. 2013; 3: 415.

66. Hall FM. Arthrography: past, present, and future. AJR Am J Roentgenol. 1987; 149: 561-562.

67. Westesson PL, Bronstein SL. Temporomandibular joint: comparison of single- and double-contrast arthrography. Radiology. 1987; 164: 65-70.

68. Littleton JT, Vannier MD. The linear "tomogram." In: Littleton JT, Durizch ML, eds. Sectional imaging methods: a comparison; Baltimore: University Park Press. 1983; 3-16.

69. Bean LR, Omnell KA, Oberg T. Comparison between radiologic observations and macroscopic tissue changes in temporomandibular joints. Dentomaxillofac Radiol. 1977; 6: 90-106.

70. Knoernschild KL, Aquilino SA, Ruprecht A. Transcranial radiography and linear tomography: a comparative study. J Prosthet Dent. 1991; 66: 239-250.

71. Pullinger A, Hollender L. Assessment of mandibular condyle position: a comparison of transcranial radiographs and linear tomograms. Oral Surg Oral Med Oral Pathol. 1985; 60: 329-334.

72. Pullinger AG, Hollender L, Solberg WK, Petersson A. A tomographic study of mandibular condyle position in an asymptomatic population. J Prosthet Dent. 1985; 53: 706-713.

73. Blaschke DD, Blaschke TJ. Normal TMJ bony relationships in centric occlusion. J Dent Res. 1981; 60: 98-104.

74. Brand JW, Whiner JG Jr, Anderson QN, Keenan KM. Condylar position as a predictor of temporomandibular joint internal derangement. Oral Surg Oral Med Oral Pathol. 1989; 67: 469-476.

75. Brand JW, Whinery JG Jr, Anderson QN, Keenan KM. The effects of temporomandibular joint internal derangement and degenerative joint disease on tomographic and arthrotomographic images. Oral Surg Oral Med Oral Pathol. 1989; 67: 220-223.

76. Pullinger AG, Solberg WK, Hollender L, Guichet D. Tomographic analysis of mandibular condyle position in diagnostic subgroups of temporomandibular disorders. J Prosthet Dent. 1986; 55: 723-729.

77. Ronquillo HI, Guay J, Tallents RH, Katzberg RW, Murphy W. Tomographic analysis of mandibular condyle position as compared to arthrographic findings of the temporomandibular joint. J Craniomandib Disord. 1988; 2: 59-64.

78. Katzberg RW, Keith DA, Ten Eick WR, Guralnick WC. Internal derangements of the temporomandibular joint: an assessment of condylar position in centric occlusion. J Prosthet Dent. 1983; 49: 250-254.

79. Dixon DC, Graham GS, Mayhew RB, Oesterle LJ, Simms D. The validity of transcranial radiography in diagnosing TMJ anterior disk displacement. J Am Dent Assoc. 1984; 108: 615-618.

80. Tsiklakis K. Cone beam computed tomographic findings in temporomandibular joint disorders. Alpha Omegan. 2010; 103: 68-78.

81. Lurie AG. Temporomandibular joint arthrography. In: Goaz PW, White SC, eds. Oral radiology: principles and interpretation. St Louis: CV Mosby, 1994; 3: 567-575.

82. Westesson PL, Omnell KA, Rohlin M. Double-contrast tomography of the temporomandibular joint. A new technique based on autopsy specimen examinations. Acta Radiol Diagn (Stockh). 1980; 21: 777-784.

83. Westesson PL. Double-contrast arthrography and internal derangement of the temporomandibular joint. Swed Dent J Suppl. 1982; 13: 1-57.

84. Duvoisin B, Klaus E, Schnyder P. Coronal radiographs and videofluoroscopy improve the diagnostic quality of temporomandibular joint arthrography. AJR Am J Roentgenol. 1990; 155: 105-107.

85. Westesson PL, Katzberg RW, Tallents RH, Sanchez-Woodworth RE, Svensson SA. CT and MR of the temporomandibular joint: comparison with autopsy specimens. AJR Am J Roentgenol. 1987; 148: 1165-1171.

86. Schellhas KP, Wilkes CH, Omlie MR, Peterson CM, Johnson SD. The diagnosis of temporomandibular joint disease: two-compartment arthrography and MR. AJR Am J Roentgenol. 1988; 151: 341-350.

87. Kaplan PA, Tu HK, Williams SM, Lydiatt DD. The normal temporomandibular joint: MR and arthrographic correlation. Radiology. 1987; 165: 177-178.

88. Hansson LG, Hansson T, Petersson A. A comparison between clinical and radiologic findings in 259 temporomandibular joint patients. J Prosthet Dent. 1983; 50: 89-94.

89. Nilner M, Petersson A. Clinical and radiological findings related to treatment outcome in patients with temporomandibular disorders. Dentomaxillofac Radiol. 1995; 24: 128-131.

90. Nabeih YB, Speculand B. Ultrasonography as a diagnostic aid in temporomandibular joint dysfunction. A preliminary investigation. Int J Oral Maxillofac Surg. 1991; 20: 182-186.

91. Manfredini D, Guarda-Nardini L. Ultrasonography of the temporomandibular joint: a literature review. Int J Oral Maxillofac Surg. 2009; 38: 1229-1236.

92. Triantafillidou K, Venetis G, Markos A. Short-term results of autologous blood injection for treatment of habitual TMJ luxation. J Craniofac Surg. 2012; 23: 689-692.

93. Habibi S, Ellis J, Strike H, Ramanan AV. Safety and efficacy of US-guided CS injection into temporomandibular joints in children with active JIA. Rheumatology (Oxford). 2012; 51: 874-877.

94. Tvrdy P. Methods of imaging in the diagnosis of temporomandibular joint disorders. Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub. 2007; 151: 133-136.

95. Vilanova JC, Barceló J, Puig J, Remollo S, Nicolau C. Diagnostic imaging: magnetic resonance imaging, computed tomography, and ultrasound. Semin Ultrasound CT MR. 2007; 28: 184-191.

96. Landes C, Walendzik H, Klein C. Sonography of the temporomandibular joint from 60 examinations and comparison with MRI and axiography. J Craniomaxillofac Surg. 2000; 28: 352-361.

97. Larheim TA, Johannessen S. Transpharyngeal radiography of mandibular condyle. Comparison with other conventional methods. Acta Radiol Diagn (Stockh). 1985; 26: 167-171.

98. Elias FM, Birman EG, Matsuda CK, Oliveira IR, Jorge WA. Ultrasonographic findings in normal temporomandibular joints. Braz Oral Res. 2006; 20: 25-32.

99. Melis M, Secci S, Ceneviz C. Use of ultrasonography for the diagnosis of temporomandibular joint disorders: a review. Am J Dent. 2007; 20: 73-78.

100. Cooper BC, Kleinberg I. Examination of a large patient population for the presence of symptoms and signs of temporomandibular disorders. Cranio. 2007; 25: 114-126.

101. Li C, Su N, Yang X, Yang X, Shi Z. Ultrasonography for detection of disc displacement of temporomandibular joint: a systematic review and meta-analysis. J Oral Maxillofac Surg. 2012; 70: 1300-1309.

102. Lathrop A, Blackburn M. Learner portfolios and hands-on workshop to facilitate and evaluate nurses' learning in obstetric ultrasound. J Obstet Gynecol Neonatal Nurs. 2011; 40: 654-661.

103. Landes C, Walendzik H, Klein C. Sonography of the temporomandibular joint from 60 examinations and comparison with MRI and axiography. J Craniomaxillofac Surg. 2000; 28: 352-361.

104. Emshoff R, Bertram S, Rudisch A, Gassner R. The diagnostic value of ultrasonography to determine the temporomandibular joint disk position. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1997; 84: 688-696.

105. Jank S, Emshoff R, Norer B, Missmann M, Nicasi A. Diagnostic quality of dynamic high-resolution ultrasonography of the TMJ--a pilot study. Int J Oral Maxillofac Surg. 2005; 34: 132-137.

106. Emshoff R, Jank S, Bertram S, Rudisch A, Bodner G. Disk displacement of the temporomandibular joint: sonography versus MR imaging. AJR Am J Roentgenol. 2002; 178: 1557-1562.

107. Emshoff R, Brandlmaier I, Bodner G, Rudisch A. Condylar erosion and disc displacement: detection with high-resolution ultrasonography. J Oral Maxillofac Surg. 2003; 61: 877-881.

108. Delle Sedie A, Riente L, Iagnocco A, Filippucci E, Meenagh G. Ultrasound imaging for the rheumatologist. VI. Ultrasonography of the elbow, sacroiliac, parasternal, and temporomandibular joints. Clin Exp Rheumatol. 2006; 24: 617-621.

109. Emshoff R, Bertram S, Strobl H. Ultrasonographic cross-sectional characteristics of muscles of the head and neck. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999; 87: 93-106.

110. Imanimoghaddam M, Davachi B, Madani AS, Nemati S. Ultrasonographic findings of masseter muscle in females with temporomandibular disorders. J Craniofac Surg. 2013; 24: 108-112.

111. Aldemir K, Üstüner E, Erdem E, Demiralp AS, Oztuna D. Ultrasound evaluation of masseter muscle changes in stabilization splint treatment of myofascial type painful temporomandibular diseases. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013; 116: 377-383.

112. Strini PJ, Strini PJ, Barbosa Tde S, Gavião MB. Assessment of thickness and function of masticatory and cervical muscles in adults with and without temporomandibular disorders. Arch Oral Biol. 2013; 58: 1100-1108.

113. Weiss PF, Arabshahi B, Johnson A, Bilaniuk LT, Zarnow D, et al. High prevalence of temporomandibular joint arthritis at disease onset in children with juvenile idiopathic arthritis, as detected by magnetic resonance imaging but not by ultrasound. Arthritis & Reumat. 1989; 58: 1189-1196.

114. Quereshy FA, Savell TA, Palomo JM. Applications of cone beam computed tomography in the practice of oral and maxillofacial surgery. J Oral Maxillofac Surg. 2008; 66: 791-796.

115. Suomalainen A, Pakbaznejad Esmaeili E, Robinson S. Dentomaxillofacial imaging with panoramic views and cone beam CT. Insights Imaging. 2015; 6: 1-16.

116. Kadesjö N, Benchimol D, Falahat B, Näsström K, Shi XQ. Evaluation of the effective dose of cone beam CT and multislice CT for temporomandibular joint examinations at optimized exposure levels.Dentomaxillofac Radiol. 2015; 44:20150041.

117. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol. 1998; 8: 1558-1564.

118. Garib DG, Calil LR, Leal CR, Janson G. Is there a consensus for CBCT use in Orthodontics? Dental Press J Orthod. 2014; 19: 136-149.

119. Talaat W, Al Bayatti S, Al Kawas S. CBCT analysis of bony changes associated with temporomandibular disorders. Cranio. 2015;.

120. Larheim TA, Abrahamsson AK, Kristensen M, Arvidsson LZ. Temporomandibular joint diagnostics using CBCT. Dentomaxillofac Radiol. 2015; 44: 20140235.

121. Rodrigues AF, Fraga MR, Vitral RW. Computed tomography evaluation of the temporomandibular joint in Class I malocclusion patients: Condylar symmetry and condyle-fossa relationship. Am J Orthod Dentofacial Orthop.2009; 136: 192–198.

122. Ikeda K, Kawamura A. Assessment of optimal condylar position with limited cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2009; 135: 495-501.

123. Manjula WS, Tajir F, Murali RV, Kumar SK, Nizam M1. Assessment of optimal condylar position with cone-beam computed tomography in south Indian female population. J Pharm Bioallied Sci. 2015; 7: 121-124.

124. Paknahad M, Shahidi S2. Association between mandibular condylar position and clinical dysfunction index. J Craniomaxillofac Surg. 2015; 43: 432-436.

125. Kurita H, Ohtsuka A, Kobayashi H, Kurashina K. A study of the relationship between the position of the condylar head and displacement of the temporomandibular joint disk. Dentomaxillofac Radiol. 2001; 30: 162-165.

126. Blaschke DD, Blaschke TJ. Normal TMJ bony relationships in centric occlusion. J Dent Res. 1981; 60: 98-104.

127. Madsen B. Normal variations in anatomy, condylar movements, and arthrosis frequency of the temporomandibular joints. Acta Radiol Diagn (Stockh). 1966; 4: 273-288.

128. Major PW, Kinniburgh RD, Nebbe B, Prasad NG, Glover KE. Tomographic assessment of temporomandibular joint osseous articular surface contour and spatial relationships associated with disc displacement and disc length. Am J Orthod Dentofacial Orthop.2002; 121: 152–161.

129. Kinniburgh RD, Major PW, Nebbe B, West K, Glover KE. Osseous morphology and spatial relationships of the temporomandibular joint: comparisons of normal and anterior disc positions. Angle Orthod. 2000; 70: 70-80.

130. Panmekiate S, Petersson A, Akerman S. Angulation and prominence of the posterior slope of the eminence of the temporomandibular joint in relation to disc position. Dentomaxillofac Radiol. 1991; 20: 205-208.

131. Ren YF, Isberg A, Westesson PL. Steepness of the articular eminence in the temporomandibular joint: tomographic comparison between asymptomatic volunteers with normal disk position and patients with disk displacement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1995; 80:258-66.

132. Kirk WS Jr. A comparative study of axial corrected tomography with magnetic resonance imagery in 35 joints. Oral Surg Oral Med Oral Pathol. 1989; 68: 646-652.

133. Ren YF, Isberg A, Westesson PL. Condyle position in the temporomandibular joint: comparison between asymptomatic volunteers with normal disk position and patients with disk displacement.Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1995; 80:101-7.

134. Dalili Z, Khaki N, Kia SJ, Salamat F. Assessing joint space and condylar position in the people with normal function of temporomandibular joint with cone-beam computed tomography. Dent Res J (Isfahan). 2012; 9: 607-612.

135. Koskinen SK, Haapamäki VV, Salo J, Lindfors NC, Kortesniemi M. CT arthrography of the wrist using a novel, mobile, dedicated extremity cone-beam CT (CBCT). Skeletal Radiol. 2013; 42: 649-657.

136. Ramdhian-Wihlm R, Le Minor JM, Schmittbuhl M, Jeantroux J, Mahon PM. Cone-beam computed tomography arthrography: an innovative modality for the evaluation of wrist ligament and cartilage injuries. Skeletal Radiol. 2012; 41: 963-969.

137. Angle JF1. Cone-beam CT: vascular applications. Tech Vasc Interv Radiol. 2013; 16: 144-149.

138. Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit. Dentomaxillofac Radiol. 2003; 32: 229-234.

139. Hintze H., Wiese M., Wenzel A. Cone beam CT and conventional tomography for the detection of morphological temporomandibular joint changes Dentomaxillofac. Radiol. 2007; 36: 192-197

140. Westesson PL, Eriksson L, Kurita K. Reliability of a negative clinical temporomandibular joint examination: prevalence of disk displacement in asymptomatic temporomandibular joints. Oral Surg Oral Med Oral Pathol. 1989; 68:551-554

141. Emshoff R, Rudisch A, Innerhofer K, Brandlmaier I, Moschen I, et al. Magnetic resonance imaging findings of internal derangement in temporomandibular joints without a clinical diagnosis of temporomandibular disorder. J Oral Rehabil. 2002; 29:516-522.

142. Orsini MG, Kuboki T, Terada S, Matsuka Y, Yamashita A. Diagnostic value of 4 criteria to interpret temporomandibular joint normal disk position on magnetic resonance images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1998; 86: 489-497.

143. Limchaichana N, Nilsson H, Ekberg EC, Nilner M, Petersson A. Clinical diagnoses and MRI findings in patients with TMD pain. J Oral Rehabil. 2007; 34: 237-245.

144. Fryback DG, Thornbury JR. The efficacy of diagnostic imaging. Med Decis Making. 1991; 11: 88-94.

145. Tasaki MM, Westesson PL, Isberg AM, Ren YF, Tallents RH. Classification and prevalence of temporomandibular joint disk displacement in patients and symptom-free volunteers. Am J Orthod Dentofacial Orthop. 1996; 109: 249-262.

146. Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach R, et al. 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: 844-860.

147. Nebbe B, Brooks SL, Hatcher D, Hollender LG, Prasad NG, et al. Magnetic resonance imaging of the temporomandibular joint: interobserver agreement in subjective classification of disk status. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000; 90: 102-107.

148. Shen P, Huo L, Zhang SY, Yang C, Cai XY. Magnetic resonance imaging applied to the diagnosis of perforation of the temporomandibular joint. J Craniomaxillofac Surg. 2014; 42: 874-878.

149. Zhang S, Yang C, Chen M, Fan X, Yun B. Magnetic resonance imaging in the diagnosis of intra-articular adhesions of the temporomandibular joint. Br J Oral Maxillofac Surg. 2009; 47: 389-392.

150. Styles C, Whyte A. MRI in the assessment of internal derangement and pain within the temporomandibular joint: a pictorial essay. Br J Oral Maxillofac Surg. 2002; 40: 220-228.

151. Venetis G, Pilavaki M, Triantafyllidou K, Papachristodoulou A, Lazaridis N. The value of magnetic resonance arthrography of the temporomandibular joint in imaging disc adhesions and perforations. Dentomaxillofac Radiol. 2011; 40: 84-90.

152. Hodler J. Technical errors in MR arthrography. Skeletal Radiol. 2008; 37: 9-18.

153. Toyama M, Kurita K, Koga K, Rivera G. Magnetic resonance arthrography of the temporomandibular joint. J Oral Maxillofac Surg. 2000; 58: 978-983.

154. Yang C, Zhang SY, Wang XD, Fan XD. Magnetic resonance arthrography applied to the diagnosis of intraarticular adhesions of the temporomandibular joint. Int J Oral Maxillofac Surg. 2005; 34: 733-738.

155. Schmid-Schwap M, Drahanowsky W, Bristela M, Kundi M, Piehslinger E. Diagnosis of temporomandibular dysfunction syndrome--image quality at 1.5 and 3.0 Tesla magnetic resonance imaging. Eur Radiol. 2009; 19: 1239-1245.

156. Wang EY, Mulholland TP, Pramanik BK, Nusbaum AO, Babb J. Dynamic sagittal half-Fourier acquired single-shot turbo spin-echo MR imaging of the temporomandibular joint: initial experience and comparison with sagittal oblique proton-attenuation images. AJNR Am J Neuroradiol. 2007; 28: 1126-1132.

157. Papachen James A, Dasarathy BV. Medical image fusion: A survey of the state of the art. Inform Fusion. 2014; 19: 4-19.

158. Kordass B. The temporomandibular joint in video motion--noninvasive image techniques to present the functional anatomy. Ann Anat. 1999; 181: 33-36.

159. Ren YF, Westesson PL, Isberg A. Magnetic resonance imaging of the temporomandibular joint: value of pseudodynamic images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1996; 81: 110-123.