Temporomandibular Joints in Asymptomatic and Symptomatic Nonpatient Volunteers: A Prospective 15-year Follow-up Clinical and MR Imaging Study[1]

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Purpose: To determine the incidence, prevalence, and progression of temporomandibular joint (TMJ) magnetic resonance (MR) imaging findings and symptoms during 15 years in adult asymptomatic and symptomatic volunteers (nonpatients).

Materials and Methods: A regional committee for medical research ethics approved the study, and informed volunteer consent was obtained. Fifty-three volunteers were examined at study inception. For clinical assessment, a self-administered questionnaire was given, followed by an interview with each volunteer at study inception, at 1 year later, and at 15 years later. Bilateral TMJ MR imaging and clinical examination were performed at inception and at 15-year follow-up. The MR images were assessed for disk position, bone status, and joint fluid. All 53 volunteers participated at 1-year follow-up, and 50 of 53 volunteers participated at 15-year follow-up; of these 50 volunteers, 47 underwent MR imaging. The Fisher exact test was used to determine differences between groups, and the Wilcoxon signed-rank test was used to determine differences in prevalence of TMJ symptoms among the three examination times.

Results: At study inception, TMJ disk displacement was observed in 31% of asymptomatic volunteers (nine of 29) compared with 89% of symptomatic volunteers (16 of 18, $P < .001$). Inceptive TMJ status was maintained after 15 years in 91% (43 of 47). Unilateral progression was observed in four volunteers (9%); one was symptomatic and three were asymptomatic. Progression involved development of new disk displacement ($n = 1$), development of new bone changes ($n = 2$), and aggravation from reducing to nonreducing disk displacement ($n = 1$). Prevalence of TMJ symptoms did not change significantly between examination times ($P = .77$). TMJ clicking was the most common clinical symptom.

Conclusion: Volunteers with mild symptoms had a prevalence of disk displacement of the same magnitude as that reported in patients, although most volunteers, symptomatic as well as asymptomatic, maintained their TMJ status during 15 years.

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Improved knowledge in regard to the natural course of orthopedic temporomandibular joint (TMJ) disorders in adult volunteers, such as disk displacement and sequelae, is important for furthering the understanding of these disorders. Prevalence of TMJ disk displacement in asymptomatic adults has been assessed in magnetic resonance (MR) imaging studies, but the long-term incidence and progression remain obscure (1–4).

Volunteers with asymptomatic TMJs have, with few exceptions, composed the reference group in controlled MR imaging studies of TMJ disorders (1–4). Comparison with data restricted to asymptomatic volunteers might, however, create some biased conclusions, because the general nonpatient population includes not only asymptomatic individuals but individuals whose symptoms have not caused them to seek treatment. Little is known about their TMJ status.

The aim of this prospective study was, therefore, to determine the incidence, prevalence, and progression of TMJ MR imaging findings and symptoms during 15 years in adult nonpatient volunteers, both asymptomatic volunteers and volunteers with TMJ symptoms.

Materials and Methods

The Regional Committee on Ethics at Umeå University, Umeå, Sweden, approved the study protocol. We obtained informed consent from each volunteer.

Volunteers

The inceptive study group comprised 53 volunteers who were enrolled in 1996. The volunteers were recruited by word of mouth and with a poster indicating that volunteers were being asked to participate in a research project that included MR imaging of the head and neck. There was no attempt to either attract or reject volunteers who had TMJ symptoms. Previous direct or indirect trauma to the head or neck constituted an exclusion criterion, as did treatment for TMJ symptoms during follow-up.

All 53 volunteers participated in a 1-year follow-up examination. After 15 years, one volunteer was deceased. The remaining 52 volunteers agreed to participate. During the follow-up period, two of these volunteers had been involved in car collisions and were exposed to indirect trauma, which caused neck symptoms but no specific TMJ symptoms. Since indirect trauma was an exclusion criterion, these two volunteers were excluded. The remaining 50 volunteers (94%) (30 female volunteers, 20 male volunteers) constituted the study population (Fig 1). The inceptive mean age was 36 years (median age, 36 years) for all subjects, with a mean age of 36 years (range, 15–57 years) for female volunteers and 36 years (range, 16–63 years) for male volunteers. The 15-year follow-up mean age was 50 years (median age, 51 years) for all subjects, with a mean age of 51 years (range, 29–71 years) for women and 50 years (range, 30–78 years) for men. Two volunteers discontinued participation after completing the questionnaire and the interview, and one completed the questionnaire and interview and underwent clinical examination but discontinued participation before undergoing MR imaging.

MR Imaging

Bilateral MR imaging of the TMJs was performed by using the same protocol for both the inception examination and the follow-up examination approximately 15 years later (mean time between examinations, 14.2 years; range, 13.8–14.6 years). At inception, MR imaging was consistently performed at Sundsvall Hospital, Sundsvall, Sweden. At the 15-year follow-up, 14 MR imaging examinations were performed at the radiology department and 28 in a mobile unit at Sundsvall Hospital. Five volunteers had moved out of town, and MR imaging, the interview, and the clinical examination were performed at the nearest hospital. Technical data regarding the MR units used and the examination protocol are accounted for in Table 1.

An axial localizing image was used to orient the long axis of the condyle in the closed-mouth position. Sagittal images were obtained perpendicular to the long axis of the condyle, and coronal images were obtained parallel to the long axis. The protocol for interpretation of the images is accounted for in Table 2.

MR images from study inception and 15-year follow-up for each volunteer were evaluated side by side to allow the three authors to perform a direct and detailed evaluation of TMJ changes over time. One author (A.I.) had 23 years of experience in evaluating TMJ MR images, another (F.B.) had 16 years of such experience, and still another (H.S.) had 5 years of such experience. The three observers evaluated 20 TMJ MR imaging examinations (for a total of 40 TMJs) together to establish clear definitions of imaging characteristics. This

Advances in Knowledge

- MR imaging revealed a low 15-year incidence and progression of temporomandibular joint (TMJ) disorders (9%) in nonpatient volunteers, either with or without TMJ symptoms.
- The prevalence of TMJ disk displacement was high in symptomatic volunteers (89%) and differed significantly from the prevalence observed in asymptomatic volunteers (31%).

Implication for Patient Care

- TMJ disk displacement and bone changes can be expected to remain stable over time in most adult nonpatients with no or mild TMJ symptoms.

Published online before print
10.1148/radiol.12112243 **Content code:** MK

Radiology 2013; 276:183–194

Abbreviation:
TMJ = temporomandibular joint

Author contributions:
Guarantors of integrity of entire study, H.S., A.I.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, all authors; clinical studies, all authors; statistical analysis, H.S., A.I.; and manuscript editing, all authors.

Conflicts of interest are listed at the end of this article.

Figure 1

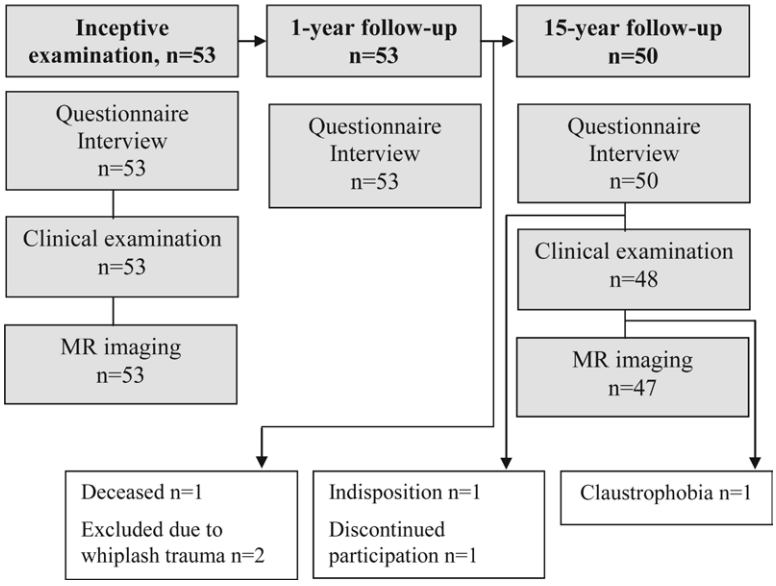

Figure 1: Flowchart shows the number of volunteers participating in the inceptive examination, the 1-year follow-up, and the 15-year follow-up. Reasons for not participating are given in white boxes. The 50 volunteers who participated from inception through the 15-year follow-up constituted the study group.

joint evaluation included 10 of the MR imaging examinations (20 TMJs total) from the present study, and the other 10 were from TMJ imaging examinations that were not part of the present study. Images from the remaining 37 MR examinations (a total of 74 TMJs) in the present study were evaluated individually and formed the basis for the calculation of interobserver agreement. The interpreters were blinded to any information in regard to case history and clinical status. When the observers' assessments differed, consensus was reached through discussion.

Determination of incidence and progression of TMJ disorders was based on the MR imaging findings at inception and follow-up and were defined as development of new disk displacement, aggravation of disk displacement (such as reducing to nonreducing and partial to complete), development or increase of structural bone changes, or development of joint effusion (Table 2).

Questionnaire and Interview

The volunteers completed the same self-administered questionnaire at both inception and follow-up appointments. The questionnaire comprised 38 items, both multiple-choice questions and open-ended questions, which required a written answer. The questions concerned health history, medication, head and neck symptoms, duration of symptoms, and history of trauma. The TMJ questions were related to previous and current pain and dysfunction. When TMJ symptoms were reported, questions in regard to the time of onset and location (whether the left, the right, or both TMJs) were asked. TMJ pain was assessed at rest, during chewing, and at wide mouth opening by using numerical rating scales. The scales ranged from zero to five, anchored on each end by "no pain" and "extreme pain." Other TMJ symptoms assessed were clicking, crepitus, transient locking, and locking with restricted mandibular movement.

The interviews were undertaken by three trained members of the research team, one for each of the three study occasions. At the 15-year follow-up, another author replaced the interviewing author on four occasions. The interviewers were blinded to the results of the present and previous examinations. The interviewer asked sequential questions about reported TMJ symptoms and ascertained that the symptoms emanated from the TMJ site and that the correct side was reported.

Clinical TMJ examinations were performed at inception and at 15-year follow-up and included palpation of the TMJs for detection of tenderness, TMJ clicking and crepitus, and range of movement. At inception, the examiner was a physician on our research team who had been trained by the principal investigator (A.I.) during a 2-year period. At follow-up, the examiners (A.I., H.S.) had 35 years and 10 years of experience in TMJ clinical examination, respectively. The clinically registered TMJ signs contributed to the classification of volunteers into asymptomatic and symptomatic subgroups, in accordance with data in previous publications (1,2,4).

Statistics

Symptomatic volunteers included individuals who reported TMJ symptoms or had clinical TMJ signs or both at one or more examinations. Volunteers with no TMJ symptoms, either self-reported or clinical, at any of the three examinations were classified as asymptomatic.

The Fisher exact test was used to compare the prevalence of disk displacement and type of disk displacement (partial or complete) between asymptomatic and symptomatic volunteers and between male and female volunteers. The Wilcoxon signed-rank test was used to compare the prevalence of TMJ symptoms among the three examination times. All reported *P* values (significance level of .05) were based on two-sided tests. The κ statistic was used to measure interobserver agreement. The κ values were interpreted by following the guidelines of Landis and Koch (7), which were adapted by Altman (8) (up to 0.20, poor; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, good; and 0.81–1.00, very good). For the purpose of κ analysis, disk position was categorized as normative superior or displaced, structural bone conditions were categorized as normative or deviant (ie, bone changes) for the merged information from the bone joint components,

Table 1

MR Equipment and Technical Data at Inception and 15-Year Follow-up at MR Site

Parameter	Sundsvall Hospital		Mobile MR Unit Stationed in Sundsvall	Uppsala University Hospital	Stockholm South General Hospital	Östersund Hospital
	Inception	Follow-up				
No. of MR imaging examinations	47	14	28	3	1	1
MR equipment	Magnetom Impact 1-T unit with double-loop array coil*	Magnetom Harmony 1-T unit with double-loop array coil*	Signa 1.5-T HDxt unit with dual-array adapter surface coil†	Achieva 1.5-T unit with SENSE Flex-S coil‡	Magnetom Symphony 1.5-T unit with head matrix coil*	Signa 1.5-T HDxt unit with cervical-thoracic-lumbar spine array coil†
Imaging sequence	Spin echo	Spin-echo T1-weighted, turbo spin-echo dual imaging	Fast spin echo	Turbo spin echo	Turbo spin echo	Fast spin echo
Field of view (cm)	12.5 for sagittal, 10 for coronal	15	12	12	14, 20 × 23 coronal, sagittal, open mouth	17
No. of signals acquired	3	2 for sagittal, 1 for coronal	1.5 for T1-weighted, 1 for dual imaging	2 for T1-weighted, 1 for dual imaging	2, 1 proton density–weighted sagittal	1, 0.5, dual imaging, sagittal
Matrix	256 × 192 for T1-weighted, 256 × 190 for dual imaging	256 × 192	256 × 192	256 × 256	320 × 320 for T2-weighted sagittal, 320 × 265 for T1-weighted and proton density–weighted sagittal, 512 × 448 for coronal open-mouth position	256 × 192
Section thickness (mm)	3, with no gap	3, with no gap	3 for sagittal, 2 for coronal, with no gap	3 for sagittal, 2 for coronal, with no gap	3, with no gap	3 for sagittal and 2 for coronal with 0.3 gap and 0.2 gap, respectively
Sagittal imaging with closed-mouth position						
TR/TE for T1-weighted	480/15	482/15	420/10	456/14	550/13	420/10
TR/TE for proton density–weighted imaging	2199/17, dual imaging	4000/19, dual imaging	2440/10, dual imaging	2300/13, dual imaging	2500/12	2340/12, dual imaging
TR/TE for T2-weighted	2199/85, dual imaging	4000/112, dual imaging	2440/104, dual imaging	2300/104, dual imaging	3650/95	2340/96, dual imaging
Sagittal imaging with open-mouth position						
TR/TE for proton density–weighted imaging	2199/17, dual imaging	4000/19, dual imaging	2440/10, dual imaging	2300/13, dual imaging	2950/11	2340/12, dual imaging
TR/TE for T2-weighted imaging	2199/85, dual imaging	4000/112, dual imaging	2440/104, dual imaging	2300/104, dual imaging	2950/92	2340/96, dual imaging

Table 1 (continues)

Table 1 (continued)

MR Equipment and Technical Data at Inception and 15-Year Follow-up at MR Site

Parameter	Sundsvall Hospital: Inception	Sundsvall Hospital: Follow-up	Mobile MR Unit Stationed in Sundsvall	Uppsala University Hospital	Stockholm South General Hospital	Östersund Hospital
Coronal imaging with closed-mouth position						
TR/TE for proton density–weighted imaging	2000/17, dual imaging	3200/19, dual imaging	2440/10, dual imaging	2300/14, dual imaging	2950/11	2400/12, dual imaging
TR/TE for T2-weighted imaging	2000/85, dual imaging	3200/112, dual imaging	2440/104, dual imaging	2300/110, dual imaging	2950/92	2400/99, dual imaging

Note.—Uppsala University Hospital is in Uppsala, Sweden; Stockholm South General Hospital is in Stockholm, Sweden; and Östersund General Hospital is in Östersund, Sweden. Dual imaging = proton density–weighted and T2-weighted imaging, TR/TE = repetition time msec/echo time msec.

* Siemens, Erlangen, Germany.

† GE Medical Systems, Milwaukee, Wis.

‡ Philips Medical Systems, Best, the Netherlands.

and joint fluid was categorized as having effusion or no effusion.

Results

TMJ Symptoms

Twenty-nine volunteers were asymptomatic, and 18 volunteers were symptomatic. Of the symptomatic group, 11 had persistent symptoms throughout the study, and seven had fluctuating symptoms between examination time points.

There was no significant difference between the three examination occasions in terms of prevalence of volunteers that reported TMJ symptoms. At study inception, 10 of the 50 volunteers (20%) reported TMJ symptoms, a prevalence that remained the same 1 year later (10 of 50) and showed no significant difference at 15-year follow-up (nine of 50, 18%) ($P = .77$) (Fig 2). One volunteer reported TMJ pain (grade 2) at inception, three volunteers had pain (grade 3) at 1-year follow-up, and two volunteers had pain (grade 1) at 15-year follow-up. Four volunteers had clinical signs, which they were unaware of.

None of the symptomatic volunteers received specific treatment for their TMJ symptoms during the study period. When specifically asked, no participant considered treatment to be necessary. Unilateral disk displacement was observed at both MR imaging examinations in one volunteer. The initial painful clicking and locking ceased during the 15-year follow-up period, after he used an occlusal splint owing to bruxism. Two other volunteers with normative superior disk positions had used an occlusal splint owing to bruxism for a time during the follow-up period.

MR Findings at Inception

At inception, TMJ disk displacement was observed in 25 of 47 volunteers (53%) and in 39 of 94 TMJs (41%) (Tables 3–6). Disk displacement was significantly more prevalent in women (18 of 27, 67%) than in men (seven of 20, 35%) ($P = .042$) (Table 7). The prevalence of disk displacement was significantly higher in symptomatic volunteers than in asymptomatic volunteers (89% vs

Table 2

MR Imaging Interpretation Protocol

Parameter	Definition
Disk position*	
Normative superior	Posterior band of disk is superior relative to condyle or anterior prominence of condyle articulates against central thin zone of disk, and disk is located symmetrically on top of condyle in the coronal view
Disk displacement with reduction	Disk position other than normative superior; disk reduces to normative position relative to condyle at opening of mouth
Disk displacement without reduction	Disk remains displaced relative to condyle at opening of mouth
Type of disk displacement†	
Partial	Disk displacement observed in some but not all of the oblique sagittal sections of the TMJ, or lateral or medial displacement observed
Complete	Disk displacement observed in all oblique sagittal sections of the TMJ
Bone status‡	
Normative	Rounded or slightly remodeled bone with intact cortex
Bone changes	Loss of rounded contour of bone surface (flattening); deviation from normative shape, such as concavity in the outline of the surface (deviating form); loss of continuity of surface (erosion); marginal hypertrophy with sclerotic borders and exophytic angular bone formation from surface (osteophyte); increased thickness of cortex in load-bearing areas (sclerosis); cavity below surface deviates from normative marrow pattern (subchondral cyst); decreased T1 signal and increased T2 signal deviate from normative marrow (edema pattern);decreased T1 and T2 signal deviate from normative marrow (sclerosis pattern), or there is a combination of edema pattern and sclerosis pattern (osteonecrosis) §
Joint fluid‖	
No effusion	There are no high-intensity T2 signals from the TMJ compartments, or there are dots or lines of high-intensity T2 signals along the articular surfaces
Effusion	There are more than the amount of high-intensity T2 signals than are defined for "no effusion"

* Tasaki et al (1).

† Larheim et al (4).

‡ Ahmad et al (5) (flattening, deviating form, erosion, osteophyte, sclerosis, subchondral cyst). Larheim et al (6) (edema, osteonecrosis, joint fluid) (minor modifications).

§ Flat surface not combined with other bone changes was considered normative.

‖ Larheim et al (6) (edema, osteonecrosis, joint fluid) (minor modifications).

Figure 2

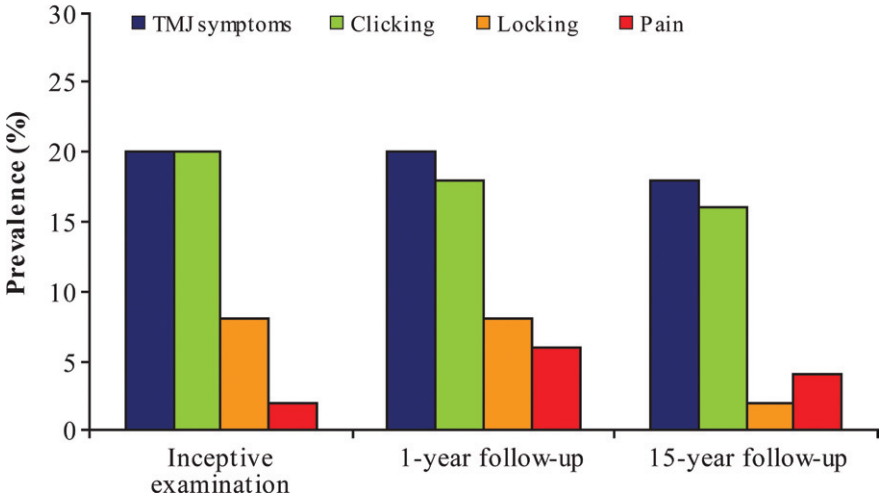

Figure 2: Graph shows prevalence of self-reported TMJ symptoms in volunteers ($n = 50$) at inception, 1-year follow-up, and 15-year follow-up. TMJ symptoms included clicking, crepitation, locking, and pain.

31%, $P < .001$). Disk displacement was partial in 10 of 18 asymptomatic TMJs (56%) compared with seven of 21 symptomatic TMJs (33%), with no significant difference between groups ($P = .206$). Consequently, there was no significant difference between groups regarding prevalence of complete disk displacement. Effusion was observed in 14 of 94 TMJs (15%) in 11 volunteers and was invariably associated with disk displacement. Effusion was present in seven symptomatic TMJs and in seven asymptomatic TMJs. Structural bone changes were observed unilaterally in only one symptomatic volunteer.

MR Findings at 15-year Follow-up versus Inception

Most volunteers maintained their inceptive TMJ status at 15-year follow-up

in that 43 of 47 volunteers (91%) had unaltered TMJ disk position and bone status and 90 of 94 TMJs (96%) maintained the inceptive status after 15 years (Figs 3, 4).

Over the 15-year study period, incidence or progression of disk status was observed in two of 47 (4%) of the volunteers (Tables 5, 6). One of them developed unilateral asymptomatic partial disk displacement with reduction. In the other volunteer, one TMJ progressed from having symptomatic complete reducing disk displacement at inception to having nonreducing disk displacement with effusion at follow-up (Fig 5). Another two asymptomatic volunteers (two of 47, 4%) developed unilateral structural bone changes during the study period. One of these volunteers developed a concavity on the superior surface of the condyle in a TMJ, with normative superior disk position on both MR imaging occasions. The other volunteer developed a concavity on the superoposterior aspect of the condyle. This TMJ displayed a complete reducing disk displacement and effusion at inception, as well as at 15-year follow-up (Fig 6). No improvement in disk position was observed in any of the 39 TMJs with disk displacement at inception. All 14 TMJs with effusion at inception also had effusion at follow-up.

The interobserver agreement in regard to TMJ MR imaging findings was very good. The κ value was 0.96 for disk position, 0.95 for joint effusion, and 0.98 for structural bone changes.

Volunteers Who Did Not Undergo MR Imaging at 15-Year Follow-up

Three participating volunteers did not undergo MR examination at the 15-year follow-up. Their TMJ disk positions at inception were bilaterally superior, bilaterally displaced with reduction, and unilaterally displaced without reduction, respectively. None of them had TMJ symptoms at any of the three examination times. The deceased volunteer had inceptive superior disk position bilaterally and was asymptomatic at inception and after 1 year.

The two volunteers that were excluded owing to indirect neck trauma

Table 3

Prevalence of TMJ Disk Position in Asymptomatic and Symptomatic Volunteers

Disk Position	No. of Asymptomatic Volunteers ($n = 29$)	No. of Symptomatic Volunteers ($n = 18$)*	*P* Value†
Superior disk position	20 (69)	2 (11)	. . .
Disk displacement	9 (31)‡	16 (89)	<.001
Partial disk displacement			
Unilateral	2	4	. . .
Bilateral	3	1	. . .
Complete disk displacement			
Unilateral	0	5	. . .
Bilateral	3	4	. . .
Partial and complete disk displacement,bilateral	1	2	. . .

Note.—Numbers in parentheses are percentages.

* Symptomatic volunteers had unilateral or bilateral TMJ symptoms.

† According to the Fisher exact test (significance level of .05).

‡ One volunteer developed unilateral partial disk displacement during the follow-up period, resulting in 19 asymptomatic volunteers with superior disk positions at 15-year follow-up.

Table 4

Prevalence of Disk Displacement in Asymptomatic and Symptomatic TMJs

Parameter	No. of Asymptomatic TMJs ($n = 65$)	No. of Symptomatic TMJs* ($n = 29$)	*P* Value†
Superior disk position	47 (72)‡	8 (28)	. . .
Disk displacement	18 (28)	21 (72)	<.01
Partial	10	7	.206
Complete	8	14	.206

Note.—Numbers in parentheses are percentages.

* Unilateral or bilateral symptoms occurred in 18 subjects.

† According to the Fisher exact test (significance level of .05).

‡ One TMJ developed partial disk displacement during the follow-up period, resulting in 46 asymptomatic TMJs with superior disk position at 15-year follow-up.

Table 5

TMJ Disk Position in 94 TMJs at 15-year Follow-up versus Inception

MR Finding at Inceptive Examination	MR Finding at 15-year Follow-up: Superior Disk Position ($n = 54$)	Disk Displacement with Reduction ($n = 32$)	Disk Displacement without Reduction ($n = 8$)
Superior disk position ($n = 55$)	54*	1	0
Disk displacement with reduction ($n = 32$)	0	31*	1
Disk displacement without reduction ($n = 7$)	0	0	7*

Note.—Data are number of TMJs.

* TMJs with maintained disk position at 15-year follow-up.

Table 6

TMJ Disk Position in 47 Volunteers at 15-year Follow-up versus Inception

	MR Finding at 15-year Follow-up		
MR Finding at Inceptive Examination	Bilateral Superior Disk Position ($n = 21$)	Unilateral Disk Displacement ($n = 12$)	Bilateral Disk Displacement ($n = 14$)
Bilateral superior disk position ($n = 22$)	21*	1	0
Unilateral disk displacement ($n = 11$)	0	11*	0
Bilateral disk displacement ($n = 14$)	0	0	14*

Note.—Data are number of volunteers.

* Volunteers with maintained TMJ disk position at 15-year follow-up.

Table 7

Prevalence of TMJ Disk Displacement in Women versus Men

	Asymptomatic Volunteers		Symptomatic Volunteers	
No. of Volunteers	No. of Volunteers	No. of Volunteers with Disk Displacement	No. of Volunteers	No. of Volunteers with Disk Displacement
Total	29	9 (31)	18	16 (89)
Women ($n = 27$)*	12	5 (42)	15	13 (87)
Men ($n = 20$)*	17	4 (24)†	3	3 (100)

Note.—Numbers in parentheses are percentages.

* Disk displacement in women (18 of 27, 67%) versus men (seven of 20, 35%) was significantly different at $P = .042$ (according to the Fisher exact test, with a significance level of .05).

† One man developed disk displacement during the follow-up period, resulting in five asymptomatic men with disk displacement at 15-year follow-up.

induced by a car collision during the follow-up period were examined fully at the 15-year follow-up. At inception, one of them was asymptomatic, with reducing disk displacement in one joint and nonreducing displacement in the contralateral joint. At the 15-year follow-up, the reducing disk displacement had progressed to be nonreducing and symptomatic. The other volunteer had unilateral asymptomatic reducing disk displacement at inception, and the disk status remained the same at the 15-year follow-up, but with the new development of bilateral TMJ pain. The time of onset of the TMJ symptoms relied on the patients' recall and, hence, the temporal order of car collision and onset of TMJ symptoms is uncertain.

Discussion

At MR imaging, the 15-year prospective follow-up yielded a prevalence of TMJ disk displacement of the same high magnitude in symptomatic nonpatient volunteers as that reported previously in patients (1–4), and this prevalence differed significantly from that seen in asymptomatic volunteers. On the other hand, the incidence and the progression of TMJ disorders in nonpatient volunteers with symptoms were as low as those in the asymptomatic volunteers and thereby contrasted with the considerably higher progression that has been reported in patients (9,10). These results point to the need for including a symptomatic nonpatient group in the design of controlled studies of patients with TMJ disorders to avoid potentially biased results in the future.

Another consequence of failure to acknowledge the group of symptomatic nonpatients is pertinent to conclusions. Investigators of previous controlled studies (1,2,4) have reported a strong association between disk displacement and TMJ pain and dysfunction on the basis of comparisons between asymptomatic volunteers and patients with TMJ symptoms. This conclusion might be questioned because the symptomatic volunteers in this study demonstrated an 89% prevalence of disk displacement, which was not associated with pain. Hence, comparison between only patients with TMJ symptoms and asymptomatic volunteers has the potential to bias conclusions.

The prevalence of disk displacement in individuals with asymptomatic TMJs increases with age from childhood throughout adolescence (11–16). A previous MR imaging follow-up study demonstrated a high incidence of TMJ disk displacement in asymptomatic adolescents, and the results also pointed to the chronic nature of disk displacement during adolescence (14). At the inception of the present longitudinal study, one-third of the asymptomatic adult volunteers had disk displacement in at least one of their TMJs, which remained approximately the same after 15 years. The prevalence of disk displacement is in agreement with previous reports, which indicates that our material was representative of a population with asymptomatic TMJs (1–4).

Nine of 10 symptomatic nonpatient volunteers in the present study had unilateral or bilateral disk displacement. This prevalence is in accordance with that of patients with TMJ symptoms, of whom eight of 10 were reported to have disk displacement (1–4). The symptomatic nonpatients also resembled patients with TMJ symptoms by having a similar proportion of complete disk displacement, amounting to two-thirds in both groups (4). But symptomatic nonpatients and symptomatic patients had different proportions of bilateral disk displacement. A lower proportion of bilateral TMJ disk displacement was found in the symptomatic nonpatient volunteers in this study than that reported in patients with TMJ symptoms (1,2,4). The high number

Figure 3

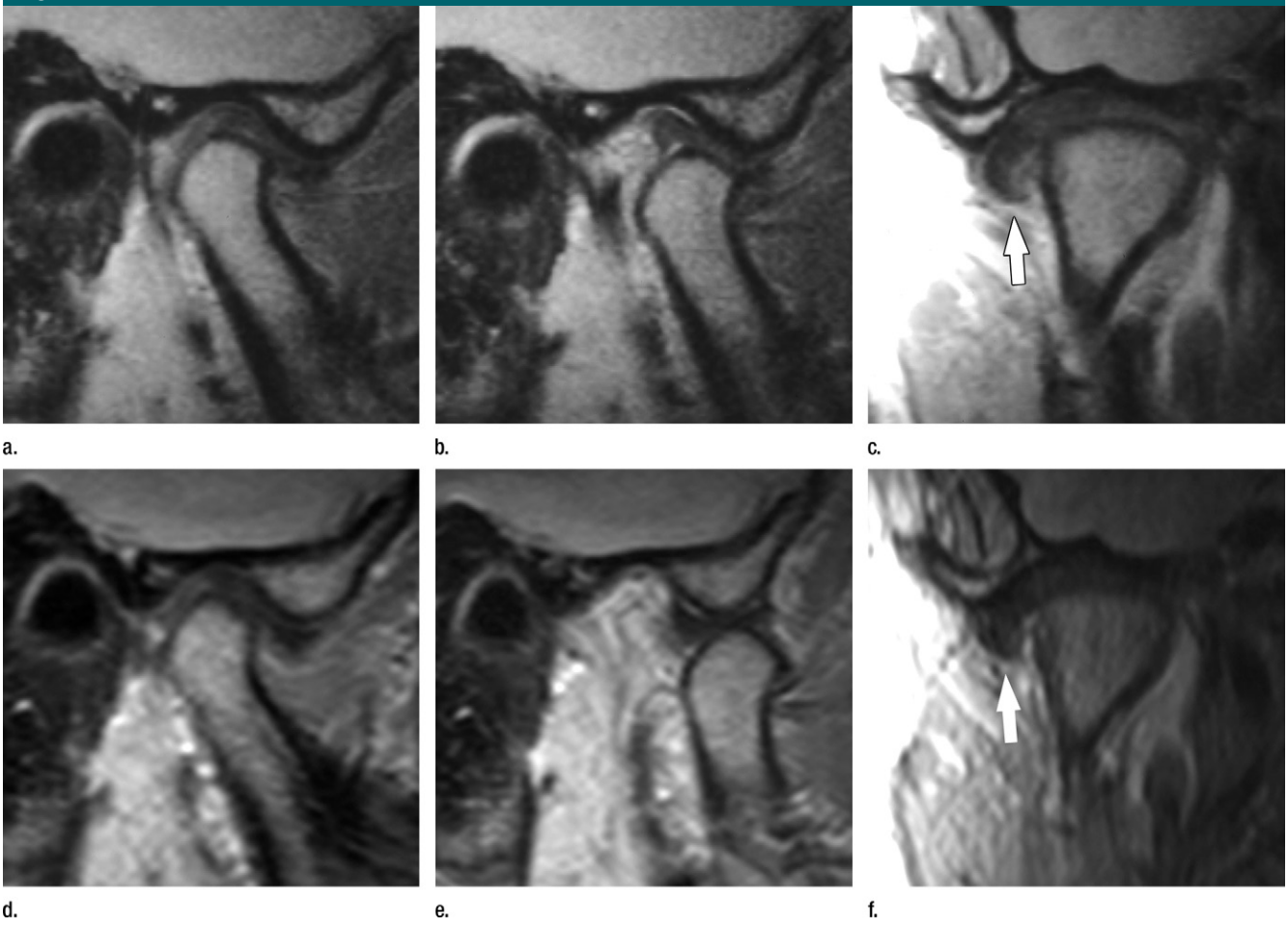

Figure 3: MR images of lateral TMJ disk displacement with reduction (arrows, **c, f**) at inception and at 15-year follow-up in a 42-year-old man (27 years old at study inception). Proton density–weighted sagittal images (2199/17) were obtained at inception in **(a)** closed-mouth and **(b)** open-mouth positions, and **(c)** coronal image (2000/17) was obtained in closed-mouth position. **(d–f)** Corresponding images at 15-year follow-up (4000/19, sagittal images; 3200/19, coronal images) show maintained TMJ status. Note the similarity between images obtained in both sagittal and coronal imaging planes at the differing time points.

of bilateral disk displacements in patients with TMJ symptoms can be associated with systemic factors, such as deviant collagen composition and general joint laxity, as well as hormonal factors (17–21).

Different studies show that progression of TMJ disk displacement is positively associated with symptom intensity. When symptoms are severe, with temporary locking and pronounced pain, 20% of patients progress from having reducing to nonreducing disk displacement within 6 months (9). Investigators (10) who conducted a follow-up study of patients with reducing disk displacement, whose symptoms had brought them to seek treatment, reported 9% progression after 3 years. In the present study, one in 13 symptomatic volunteers progressed from having reducing to nonreducing disk displacement over 15 years. The latter two progression rates appear similar, but the two studies differ in that in our study, we examined a smaller group but provided a much longer follow-up period. The long-term disk stability found in adult asymptomatic TMJs, as well as in TMJs with mild symptoms in our study, points to no or little indication for treatment in this group, whereas disk displacement associated with severe symptoms often requires treatment. Indication for treatment in the growing individual is, however, broader than that in adults because of the adverse effect exerted on facial growth by disk displacement, whether asymptomatic or symptomatic (22,23).

None of the volunteers in our study thought they had a need for TMJ treatment. One volunteer used a splint, owing to bruxism. Unilateral disk displacement with reduction was observed at both MR imaging examinations, and the inceptive painful clicking and locking had ceased at the 15-year

Figure 4

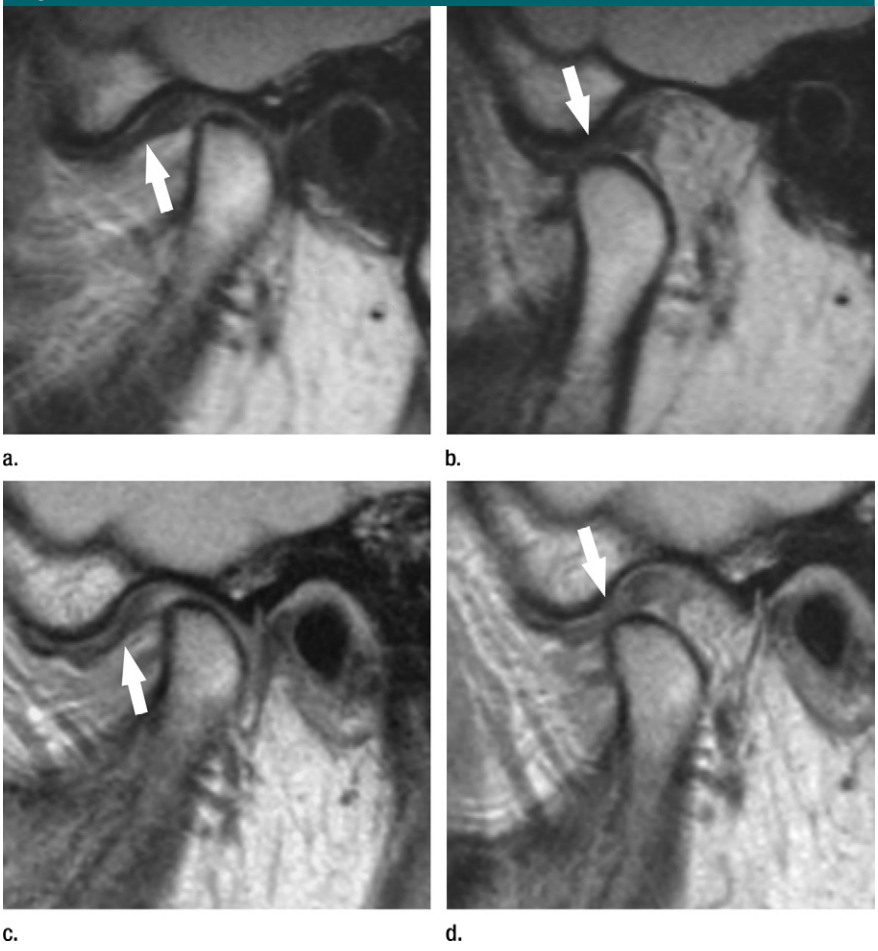

Figure 4: MR images of anterior TMJ disk displacement with reduction (arrow) at inception and at 15-year follow-up in a 37-year-old woman (22 years old at study inception). Proton density–weighted sagittal images (2199/17) were obtained in **(a)** closed-mouth and **(b)** open-mouth position at inception and **(c)** closed-mouth and **(d)** open-mouth position at 15-year follow-up (2300/13). Note maintained TMJ disk position and bone status at follow-up.

follow-up. Even though the splint was not intended for use as treatment for the symptomatic TMJ, a beneficial effect cannot be ruled out.

One of the strengths of our study was that the follow-up participation rate was 94% after 15 years (89% for MR examination). The bias caused by attrition was therefore minimized. Furthermore, there was consistency between the inceptive and follow-up MR images.

A limitation of this study was the limited number of participants in the asymptomatic and symptomatic subgroups, which did not allow for analysis of differences between men and women within subgroups.

In conclusion, investigators in future TMJ studies involving control groups need to consider including symptomatic as well as asymptomatic volunteers to avoid biased results. In contrast to asymptomatic volunteers, nonpatient volunteers with mild symptoms had a prevalence of disk displacement of the same magnitude as that reported in patients, whereas in contrast to reports of patients, most volunteers, symptomatic as well as asymptomatic, maintained their TMJ status over 15 years.

Acknowledgments: The authors thank Fredrik Wiklund, PhD, Department of Medical Epidemiology and Biostatistics, Karolinska Institute, Stockholm, Sweden, for statistical advice and analyses. The authors also thank Lars Eriksson, DDS, PhD, Department of Oral and Maxillofacial Surgery, Malmö University, Malmö, Sweden, for critical review of the manuscript.

Disclosures of Conflicts of Interest: H.S. No relevant conflicts of interest to disclose. **F.B.** No relevant conflicts of interest to disclose. **A.I.** No relevant conflicts of interest to disclose.

References

1. 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(3):249–262.
2. Katzberg RW, Westesson PL, Tallents RH, Drake CM. Anatomic disorders of the temporomandibular joint disc in asymptomatic subjects. J Oral Maxillofac Surg 1996;54(2):147–153; discussion 153–155.
3. Kahn J, Tallents RH, Katzberg RW, Moss ME, Murphy WC. Association between dental occlusal variables and intraarticular temporomandibular joint disorders: horizontal and vertical overlap. J Prosthet Dent 1998;79(6):658–662.
4. Larheim TA, Westesson PL, Sano T. Temporomandibular joint disk displacement: comparison in asymptomatic volunteers and patients. Radiology 2001;218(2):428–432.
5. Ahmad M, Hollender L, Anderson Q, 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(6):844–860.
6. Larheim TA, Katzberg RW, Westesson PL, Tallents RH, Moss ME. MR evidence of temporomandibular joint fluid and condyle marrow alterations: occurrence in asymptomatic volunteers and symptomatic patients. Int J Oral Maxillofac Surg 2001;30(2):113–117.
7. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33(1):159–174.
8. Altman DG. Some common problems in medical research. In: Practical statistics for medical research. London, England: Chapman & Hall, 1991; 404.
9. Westesson PL, Lundh H. Arthrographic and clinical characteristics patients with disk displacement who progressed to closed lock

Figure 5

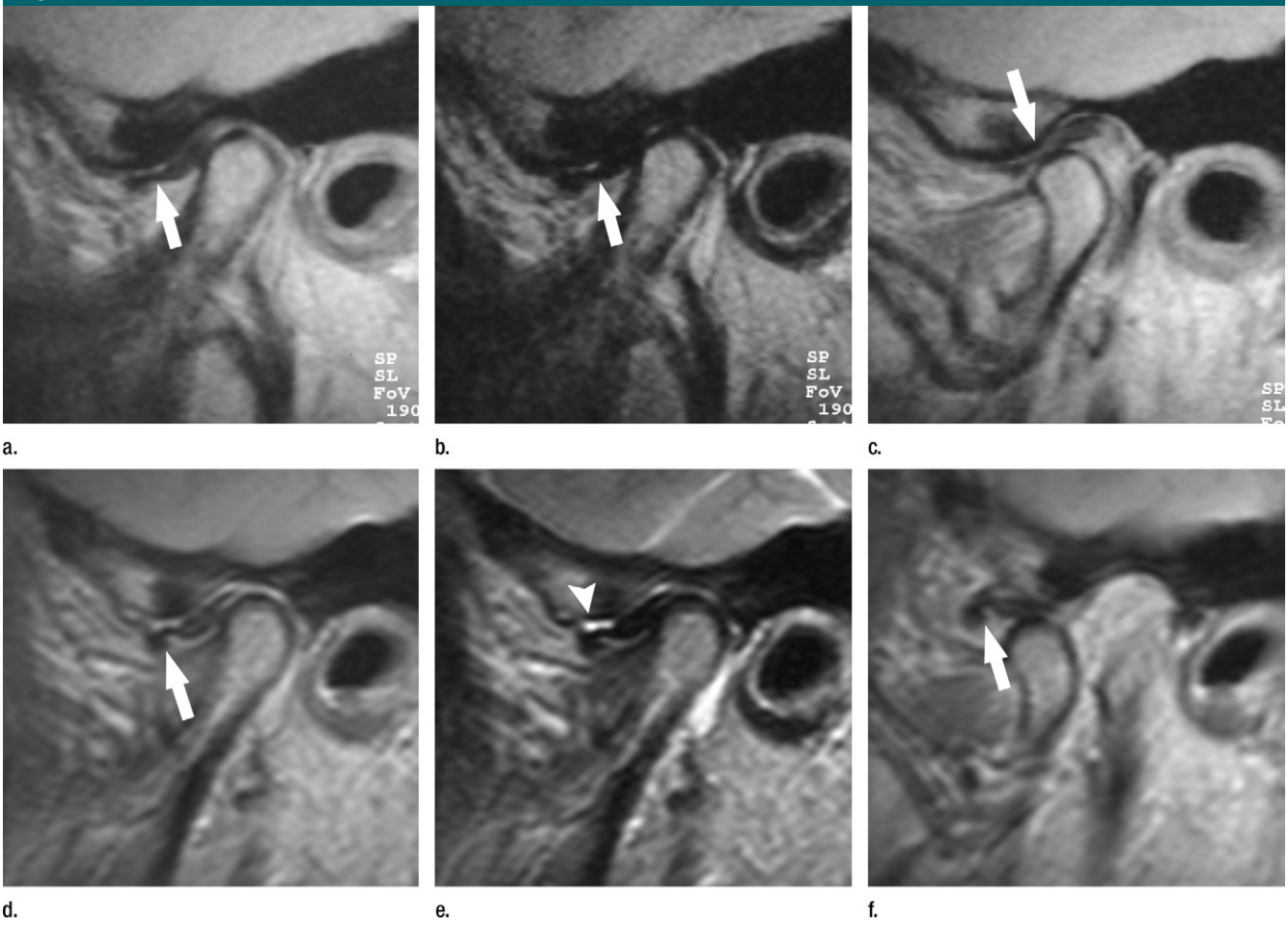

Figure 5: MR images show progression of a TMJ disorder in a 62-year-old woman (47 years old at study inception). **(a, b)** Sagittal proton density–weighted (2199/17) (**a**) and T2-weighted (2199/85) (**b**) images obtained at inception in closed mouth position show anteriorly displaced disk (arrows). **(c)** Proton density–weighted sagittal image (2199/17) obtained in open-mouth position shows reducing disk (arrow) at inception. **(d–f)** Corresponding images obtained at 15-year follow-up (4000/19, proton density–weighted images; 4000/112, T2-weighted images) show the progression to nonreducing disk (arrow, **d** and **f**) and effusion (arrowhead, **e**).

Figure 6

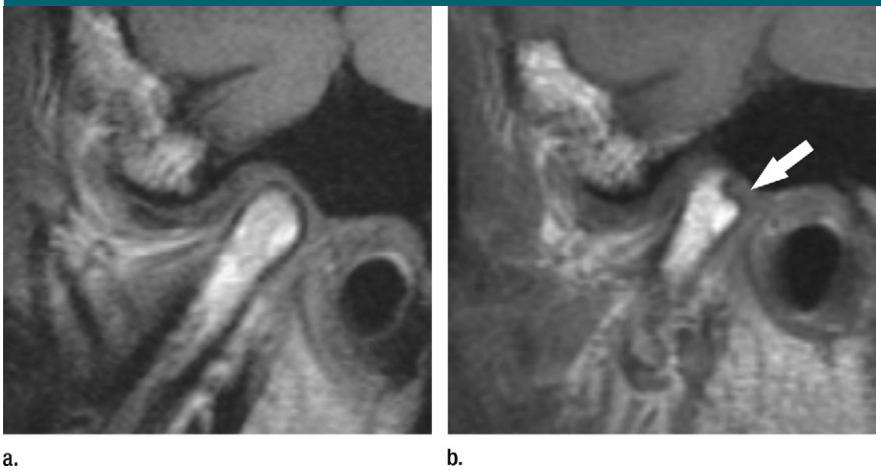

Figure 6: MR images show development of structural bone changes in a 60-year-old woman (45 years old at study inception). T1-weighted sagittal images obtained in closed-mouth position at **(a)** inception (480/15) and **(b)** 15-year follow-up (420/10). Note the concavity in the posterior part of the condyle at the 15-year follow-up (arrow, **b**).

during a 6-month period. Oral Surg Oral Med Oral Pathol 1989;67(6):654–657.

10. Lundh H, Westesson PL, Kopp S. A three-year follow-up of patients with reciprocal temporomandibular joint clicking. Oral Surg Oral Med Oral Pathol 1987;63(5):530–533.
11. Paesani D, Salas E, Martinez A, Isberg A. Prevalence of temporomandibular joint disk displacement in infants and young children. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;87(1):15–19.
12. Hans MG, Lieberman J, Goldberg J, Rozencweig G, Bellon E. A comparison of clinical examination, history, and magnetic resonance imaging for identifying orthodontic patients with temporomandibular joint disorders. Am J Orthod Dentofacial Orthop 1992;101(1):54–59.
13. Masi M, Lederman HM, Yamashita HK, de Arruda Aidar LA. Temporomandibular joint evaluation with magnetic resonance imaging in children with functional unilateral posterior crossbite, treated with rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2009;136(2):207–217.
14. Tominaga K, Konoo T, Morimoto Y, Tanaka T, Habu M, Fukuda J. Changes in temporomandibular disc position during growth in young Japanese. Dentomaxillofac Radiol 2007;36(7):397–401.
15. Kecik D, Kocadereli I, Saatci I. Condylar disc relationships and vibration energy in asymptomatic class I 9- to 12-year olds. Angle Orthod 2005;75(1):54–62.
16. Ribeiro RF, Tallents RH, Katzberg RW, et al. The prevalence of disc displacement in symptomatic and asymptomatic volunteers aged 6 to 25 years. J Orofac Pain 1997;11(1):37–47.
17. Westling L, Mattiasson A. General joint hypermobility and temporomandibular joint derangement in adolescents. Ann Rheum Dis 1992;51(1):87–90.
18. Johansson AS, Isberg A. The anterosuperior insertion of the temporomandibular joint capsule and condylar mobility in joints with and without internal derangement: a double-contrast arthrotomographic investigation. J Oral Maxillofac Surg 1991;49(11):1142–1148.
19. Westling L, Holm S, Wallentin I. Temporomandibular joint dysfunction. Connective tissue variations in skin biopsy and mitral valve function. Oral Surg Oral Med Oral Pathol 1992;74(6):709–718.
20. Abubaker AO, Raslan WF, Sotereanos GC. Estrogen and progesterone receptors in temporomandibular joint discs of symptomatic and asymptomatic persons: a preliminary study. J Oral Maxillofac Surg 1993;51(10):1096–1100.
21. Ribeiro-Dasilva MC, Peres Line SR, Leme Godoy dos Santos MC, et al. Estrogen receptor-alpha polymorphisms and predisposition to TMJ disorder. J Pain 2009;10(5):527–533.
22. Nebbe B, Major PW, Prasad NG. Adolescent female craniofacial morphology associated with advanced bilateral TMJ disc displacement. Eur J Orthod 1998;20(6):701–712.
23. Isberg A, Legrell PE. Facial asymmetry in adults following temporomandibular joint disc displacement with onset during growth. World J Orthod 2000;1(2):164–172.