Clinical Outcome of Sodium Hyaluronate Injection into the Superior and Inferior Joint Space for Osteoarthritis of the Temporomandibular Joint Evaluated by Cone-Beam Computed Tomography: A Retrospective Study of 51 Patients and 56 Joints

BCE 1 Haibin Sun
BC 1.2 Yi Su
CF 3 Ning Song
AB 1 Chunjie Li
DF 1 Zongdao Shi
DFG 1 Longjiang Li

Corresponding Authors: Chunjie Li, e-mail: lichunjie07@qq.com, Longjiang Li, e-mail: muzili63@163.com

Source of support: This study was supported by the National Natural Science Foundation of China (No. 81321002)

Background: The aim of this study was to determine the clinical effects of sodium hyaluronate injection into the superior and inferior joint space for osteoarthritis of the temporomandibular joint (TMJ) and to evaluate the joint changes using cone-beam computed tomography (CBCT).

Material/Methods: A retrospective observational clinical study included 51 patients and 56 TMJs, with a diagnosis of osteoarthritis. All patients received sodium hyaluronate injections into the superior and inferior TMJ joint spaces (articular cavities). At baseline and post-treatment the condylar bony changes were evaluated by CBCT. To evaluate TMJ function, maximum mouth opening (MMO), and Helkimo’s index was used, which included an anamnestic index (A) and a clinical dysfunction index (D). Patients were divided into short-term (<one year) and long-term (>one year) follow-up groups.

Results: In both patient follow-up groups, sodium hyaluronate injection of the superior and inferior TMJ space significantly improved MMO, the A, and the D (P<0.05). There were no significant differences between the two groups in condylar bony changes of the TMJ seen by CBCT (sclerosis, erosion, hyperplasia, and flattening) (P>0.05). CBCT showed a good predictive ability on post-treatment symptom relief following sodium hyaluronate injection into the superior and inferior TMJ space in patients with osteoarthritis of the TMJ (P=0.024).

Conclusions: The findings of this clinical and CBCT imaging study showed that sodium hyaluronate injection into the superior and inferior TMJ space in patients with osteoarthritis improved clinical symptoms, but did not control the progression of osteoarthritic joint destruction.

MeSH Keywords: Cone-Beam Computed Tomography • Hyaluronic Acid • Osteoarthritis • Prognosis • Temporomandibular Joint

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/908821

5793
Background

Temporomandibular joint (TMJ) disorders include conditions that result in clinical symptoms that may affect the masticatory musculature, the TMJ surface and joint space, and the associated regional structures [1]. Many TMJ disorders are caused by poor masticatory habits or malocclusion [2,3], which further induce functional or pathological changes of the TMJ and related structures [4]. TMJ disorders are the most common cause of pain of non-dental origin in the orofacial region [5], and occur in between 21.5–51.8% of people [6]. A recently published systematic review showed that TMJ disorders, especially osteoarthritis of the TMJ, have a negative effect on the quality of life [7], which supports the need for more research on the prevention, diagnosis, and treatment of TMJ disorders, including osteoarthritis.

Osteoarthritis of the TMJ is a slowly progressing degenerative joint disease characterized by the destruction of the mandibular condyle and glenoid fossa and is often brought about by increased load on the joint [8]. Osteoarthritis of the TMJ can result in different clinical symptoms that can vary in degree, including joint pain, crepitus, restricted motion and mouth opening, and eventually loss of joint function [9]. Currently, the treatment for osteoarthritis of the TMJ can be divided into conservative treatment and surgical treatment, which have the same primary goal of reducing pain and improving the function of the TMJ.

Conservative treatments for TMJ disorders include isometric exercises, analgesic treatment, the use of oral anti-inflammatory drugs, physical therapy, intra-articular drug injections, and correction of occlusal abnormalities [10–12]. While these conservative treatments are often encouraged for osteoarthritis of the TMJ, few have been proven to be effective [13–15].

Among the compounds used for intra-articular injection in the treatment of osteoarthritis of the TMJ, sodium hyaluronate has been used widely in the TMJ and other large joints, such as the knee, ankle, and hip. Sodium hyaluronate plays an important role in maintaining intra-articular homeostasis by improving the physiological function of the synovial fluid and protects the articular cartilage by an anti-inflammatory mechanism [16,17]. We have recently reported that sodium hyaluronate injection into the superior and inferior TMJ space (double chamber) is a treatment that is acceptable to patients and clinicians [11,18,19]. The clinical effectiveness and safety of sodium hyaluronate have been supported by a previously published systematic review and by clinical studies, most of the previously published reports focused on the changes in the clinical signs and symptoms following intra-articular injection of sodium hyaluronate [20–24]. Few studies have examined the radiological changes in bone and cartilage following intra-articular injection of sodium hyaluronate [25,26].

The aim of this study was to determine the clinical effects of sodium hyaluronate injection into the superior and inferior joint space of the TMJ in patients diagnosed with osteoarthritis and to evaluate the joint changes using cone-beam computed tomography (CBCT). A further aim was to determine whether there were any possible correlations between the clinical manifestations of osteoarthritis of the TMJ and the radiological bony changes, using baseline CBCT evaluation, to attempt to predict the clinical outcome following treatment.

Material and Methods

Study design

In the clinical setting of the Oral and Maxillofacial Surgery Clinic, West China Hospital of Stomatology, Sichuan University, a retrospective study was conducted that involved patient clinical chart and record review, between December 2009 and December 2013. The study inclusion criteria were as follows: a diagnosis of osteoarthritis of the temporomandibular joint (TMJ) based on the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) and confirmed by cone-beam computed tomography (CBCT) [27,28]; at least six months of patient follow-up data were required; patients underwent injection of sodium hyaluronate into the superior and inferior TMJ space; and CBCT was conducted before the first injection and during the follow-up period. The exclusion criteria were: patients who had received treatment for any other type of TMJ disorder, including drug treatment, during the previous four weeks; patients who had hypersensitivity diseases or were allergic to multiple drugs; patients with severe systemic diseases or infection in the region of the TMJ; patients who were unable to attend follow-up visits when required.

This study was approved by the Institutional Review Board (IRB) of the West China School of Stomatology (Ref: 2009022). Informed consent was obtained from the study participants.

Patients were divided into short-term (one year) and long-term (three-year) follow-up groups.

Treatment modalities

During four consecutive weeks, all patients in the study received four injections of 20 mg in 2 ml of sodium hyaluronate (Sofast) (Bloomage Freda Biopharm Co Ltd., Shandong, China) into the superior and inferior TMJ joint spaces. The details of the injection preparations and procedures have been detailed in a previous publication from our group [18]. Other treatment modalities were provided, if required, including oral non-steroidal anti-inflammatory drugs (NSAIDs), or glucosamine chloride, for a maximum duration of three months.
Evaluation of clinical symptoms

The clinical signs and symptoms were scored for each study participant based on the Helkimo Index, including the clinical dysfunctional index (Di) (Table 1) and the anamnestic index (Ai) [29]. Also, maximal mouth opening (MMO) was recorded using Vernier calipers.

Evaluation of cone-beam computed tomography (CBCT)

All patients were scored based on CBCT imaging of the changes found in the TMJ. Two trained clinicians, with experience in TMJ disorders, conducted the imaging scoring in duplicate, and any discrepancies were resolved by discussion with or without another trained clinicians, with experience in TMJ disorders. The CBCT scoring system for osteoarthritis of the TMJ included extent and severity of the joint changes.

For the severity assessment for osteoarthritis of the TMJ, the mandibular condylar bony change was classified as sclerosis (including cysts), erosion, hyperplasia (or the presence of osteophytes), and condylar flattening. Flattening was scored 0 (absent), and 1 (present). Other parameters were all scored from 0–2, and included the severity of bony destruction (0, none; 1, present with a height ≤1 mm; 2, present with a height ≥1 mm).

Statistical analysis

Data were analyzed using SPSS version 17.0 (SPSS, IBM, Chicago, IL, USA) and GraphPad Prism. Paired sample t-tests were used to compare the baseline results with the post-treatment results. The Spearman’s rank correlation test was used to evaluate the correlation between the osseous destruction and the clinical findings. The level of significance (P) was set at 0.05.

Results

A total of 56 temporomandibular joints (TMJs) from 51 patients were included in this study, as five of the patients had...
bilateral osteoarthritis of the TMJ, and received a bilateral sodium hyaluronate injection into the superior and inferior joint space. However, no patient or TMJs overlapped between the short-term and long-term follow-up groups. The clinical and demographic characteristics for each patient included in the study are shown in Table 2.

Table 2. Demographic characteristics of included patients.

| Items                   | Short term group | Long term group |
|-------------------------|------------------|-----------------|
| Number of TMJs          | 26               | 30              |
| Number of patients (Male/Female) | 22 (5/17)       | 29 (5/22)       |
| Age                     | 30.31±14.75      | 34.37±16.39     |
| Disc displacement with reduction | 5               | 3               |
| Disc displacement without reduction | 8               | 14              |
| Follow-up period         | 7.85±2.72        | 19.83±6.20      |

TMJ – temporomandibular joint.

Injection of sodium hyaluronate into the superior and inferior TMJ space did not affect osteoarthritic bony destruction of the joint

When evaluated by cone-beam computed tomography (CBCT), injection of sodium hyaluronate into the superior and inferior TMJ space in patients with osteoarthritis showed no significant effect on reducing or preventing the progression of bony destruction in the short-term and long-term assessment.

Figure 1. The effect of treatment with injection of sodium hyaluronate into the superior and inferior joint space for osteoarthritis of the temporomandibular joint (TMJ) assessed by clinical parameters and cone-beam computed tomography (CBCT). (A) Results of the cone-beam computed tomography (CBCT) evaluation. (B) In the evaluation of temporomandibular joint (TMJ) function, the use of Helkimo’s index includes a clinical dysfunction (Di). Results of the Helkimo clinical dysfunction index (Di). (C) In the evaluation of temporomandibular joint (TMJ) function, the use of Helkimo’s index includes an anamnestic index (Ai). Results of the Helkimo Ai. (D) Results of the maximal mouth opening (MMO) recorded using Vernier calipers. * P<0.05; ** P<0.01 compared with baseline. SH – sodium hyaluronate; TMJ – temporomandibular joint; CBCT – cone-beam computed tomography; MMO – maximal mouth opening; Di – Helkimo clinical dysfunction.
Table 3. Effect of HS on bone destructions.

| Group       | Bony change | Pre-injection | Post-injection | P   |
|-------------|-------------|---------------|----------------|-----|
| Short term  | Sclerosis   | 0.58±1.27     | 0.85±2.13      | 0.497 |
|             | Erosion     | 1.50±2.16     | 1.58±2.25      | 0.759 |
|             | Hyperplasia | 1.92±3.39     | 2.35±3.24      | 0.584 |
|             | Flattening  | 1.12±1.48     | 1.15±1.43      | 0.870 |
|             | Total       | 4.73±3.73     | 5.50±3.67      | 0.338 |
| Long term   | Sclerosis   | 2.20±3.87     | 2.03±3.26      | 0.764 |
|             | Erosion     | 1.03±2.53     | 0.30±0.95      | 0.064 |
|             | Hyperplasia | 2.87±3.38     | 3.03±3.54      | 0.721 |
|             | Flattening  | 0.83±1.12     | 0.87±1.14      | 0.839 |
|             | Total       | 7.13±4.40     | 6.53±4.82      | 0.390 |

groups (P>0.05) (Figure 1A). Also, when the bony destruction parameters were evaluated separately, no positive effects from treatment with sodium hyaluronate were observed (Table 3). For some patients, CBCT showed that flattening, sclerosis, hyperplasia, and erosion of the mandibular condyle of the TMJ showed an improvement after injection of sodium hyaluronate (Figure 2), but disease progression was observed for most of the patients studied (Figure 3).

Injection of sodium hyaluronate into the superior and inferior TMJ space reduced the clinical signs and symptoms of osteoarthritis of the TMJ

The effect of injection of sodium hyaluronate into the superior and inferior TMJ space in patients on the clinical signs and symptoms of osteoarthritis of the TMJ were more positive. Helkimo’s index was used, which included a clinical dysfunction index (DI) which significantly decreased in both the short-term and long-term observation patient groups (P<0.01, and P<0.05, respectively). The Helkimo anamnestic index (Ai) decreased significantly in the long-term observation patient group (P<0.05). The maximum mouth opening (MMO) measurement increased significantly in both observation groups (P<0.001, and P<0.05, respectively) (Figure 1B–1D).

CBCT imaging showed that osteoarthritic bony destruction of the TMJ did not correlate with clinical parameters

To evaluate whether CBCT imaging of the TMJ might be used to evaluate treatment effects, the following correlation tests were performed: baseline CBCT score versus baseline clinical parameters; post-treatment CBCT score versus clinical results; and changed CBCT scores (post-treatment score minus baseline) versus changed clinical results. These tests indicated no significant associations between bony destruction of the TMJ and clinical signs and (P>0.05) (Table 4).

CBCT imaging showed baseline TMJ bony destruction of the TMJ was negatively correlated with relief of clinical symptoms

To further evaluate the effect of baseline CBCT on predicting the progression of osteoarthritis of the TMJ and patient outcome following sodium hyaluronate injection into the superior and inferior joint space, a correlation between the baseline CBCT scores versus the change in clinical results showed that baseline CBCT scores were negatively predictive of the Helkimo Ai (P<0.05), but were not associated with the other changes in clinical parameter scores (P>0.05) (Table 5).

Discussion

The findings of this study showed that injection of sodium hyaluronate into the superior and inferior temporomandibular joint (TMJ) space in patients with osteoarthritis of the TMJ significantly improved clinical symptoms, including maximum mouth opening (MMO), and the components of Helkimo’s index, the anamnestic index (Ai) and the clinical dysfunction index (Di). However, using cone-beam computed tomography (CBCT) to evaluate the osteoarthritic joint changes at baseline and following treatment, no significant differences were found in the mandibular condylar bony changes of the TMJ (including sclerosis, erosion, hyperplasia, and flattening) (P>0.05). Also, there were no significant correlations between any clinical parameters and the TMJ joint changes seen on CBCT. Despite these findings, the CBCT showed that the osteoarthritic TMJ joint changes at baseline were significantly associated with patient symptom relief following injection of sodium hyaluronate into the superior and inferior TMJ space (P=0.024). Therefore, evaluation of the TMJ using CBCT in patients with osteoarthritis of the TMJ might be useful for predicting improvement in clinical symptoms.
Several previously published studies have shown that intra-articular injection of sodium hyaluronate can relieve the clinical signs and symptoms of TMJ disorders, including osteoarthritis of the TMJ [16,17,30–32]. The results of the present study support these previous findings. However, the effect of intra-articular injection with sodium hyaluronate on the destruction of the joint in patients with osteoarthritis of the TMJ has rarely been previously reported.

The first study to investigate bony destruction in osteoarthritis of the TMJ was reported in 2008 by Møystad et al., who evaluated the osseous change in 36 patients with osteoarthritis of the TMJ who were randomly allocated into the sodium hyaluronate or corticosteroid upper joint space injection groups [26]. In this previous study, at six-month follow-up, neither sodium hyaluronate nor corticosteroid injection had a significant effect on the TMJ on CBCT evaluation [26]. Similarly, Li et al. investigated 141 patients with osteoarthritis of the TMJ who were randomly allocated to upper or lower TMJ space injection with sodium hyaluronate, and found no change in the joint damage score evaluated by CBCT after three months and nine months follow-up [33]. However, when these authors investigated the remodeling scores, the lower TMJ space injection of sodium hyaluronate showed improved clinical follow-up results [33]. These two previously published studies used relatively short-term follow-up periods of less than nine months [26,33]. Therefore, until the present study, no previous study had evaluated the osseous changes of patients with osteoarthritis of the TMJ treated with sodium hyaluronate using long-term follow-up.

In the present study, data were collected to evaluate the short-term and long-term bony changes following TMJ injection with sodium hyaluronate.

**Figure 2.** The recession of osteoarthritic bony destruction of the temporomandibular joint (TMJ) following injection of sodium hyaluronate into the superior and inferior joint space, assessed by cone-beam computed tomography (CBCT) Patient 1. Fourteen months after sodium hyaluronate treatment, a relatively normal right temporomandibular joint (TMJ) contour, and bone surface compared with a flattened shape, osteophytes at the anterior surface, and sclerosis, before treatment. Patient 2. Before treatment. Erosion and sclerosis of the mandibular condyle of the temporomandibular joint (TMJ), and hyperplasia in the glenoid fossa. Eight months after treatment, a normal mandibular condyle and a relatively smooth reconstructed glenoid fossa are shown. SH – sodium hyaluronate; CBCT – cone-beam computed tomography; TMJ – temporomandibular joint.
sodium hyaluronate. For the short-term results, the findings were supported by previous publications and showed that superior and inferior joint space (double chamber) injection with sodium hyaluronate did not alter the osseous destruction in the TMJ [26,33]. As the recession of the osseous destruction may require more follow-up time, in the present study, data were collected for 30 TMJs where the follow-up information was available for a period longer than one year. During the long-term follow-up, injection of the TMJ with sodium hyaluronate still had no significant impact on avoiding destruction of the TMJ osseous structures.

The reduced clinical symptoms and signs observed in the present study, and in those of other studies, might be due to a decrease in inflammatory factors caused by the sodium hyaluronate injection rather than any effect on bone regeneration [34]. Although recent research has indicated that intra-articular sodium hyaluronate injection might increase the secretion of cartilage surface protective factors [35], there is little evidence sodium hyaluronate can accelerate bone regeneration. Some clinical reports have indicated that intra-articular injection might increase the risk of articular adhesion, which would further accelerate osseous destruction [36]. This effect might explain why bone regeneration was not found in patients with osteoarthritis of the TMJ patients after sodium hyaluronate injection. Another possible explanation is that the patients were not followed-up for long enough. In this study, the mean follow-up time was 19.32 months in the long-term group. In the future, longer follow-up times may be necessary to observe an effect of sodium hyaluronate treatment on TMJ bone regeneration.

**Figure 3.** Progression of bony destruction of the temporomandibular joint (TMJ) following injection of sodium hyaluronate into the superior and inferior joint space, assessed by cone-beam computed tomography (CBCT). Patient 3. Before treatment, slight sclerosis on the anterior surface. Six months after treatment: flattening, sclerosis, and osteophyte formation are seen on the anterior surface. Patient 4. Before treatment, sclerosis and slight flattening on the anterior surface of the mandibular condyle of the TMJ, with hyperplasia in the glenoid fossa. Nine months after treatment: increased sclerosis, osteophytes, and slight flattening on the anterior surface of the mandibular condyle are shown, but glenoid fossa hyperplasia remains unchanged. SH – sodium hyaluronate; CBCT – cone-beam computed tomography; TMJ – temporomandibular joint.
In the present study, in addition to analyzing the treatment effect of intra-articular sodium hyaluronate, there was no association between TMJ changes seen on CBCT evaluation and the clinical symptoms and signs. These findings were in accordance with most of the previously published studies, which used CBCT or X-ray scans to assess the clinical and imaging correlations [13,37,38]. However, Su et al. did find an association between the baseline CBCT scores and the baseline clinical parameters in 240 patients with osteoarthritis of the TMJ [39]. The differences between the findings of the present study and previous studies such as that of Su et al., are difficult to explain, as the method of CBCT evaluation were similar [39]. A limitation of the present study was that it did include a small number of patients (51 patients) from a single center. However, even with a larger study population, and based on the data from the present study, it is unclear whether a larger study population would show any difference in the results.

The latter part of the present study focused on the predictive ability of the baseline CBCT evaluation on the prognosis of patients with osteoarthritis of the TMJ, which has not been undertaken before. The results showed that baseline CBCT score was negatively correlated with the Helkimo anamnestic index (Ai). Therefore, the higher the CBCT score, the more symptom relief the patient will have in the long term. However, a larger, multi-center, controlled study is recommended in future to explore the predictive value of CBCT in the evaluation of patient outcome following treatment for osteoarthritis of the TMJ.

### Table 4. Correlations between clinical parameters and CBCT scores.

| Group | Comparison object | Baseline | Post-treatment | Change value |
|-------|-------------------|----------|----------------|--------------|
|       |                   | r        | P value        | r            | P value      | r            | P value      |
| Short term | Helkimo Di | -0.200  | 0.923         | -0.41        | 0.843        | -1.77        | 0.386        |
|        | Helkimo Ai | 0.054   | 0.794         | -0.483       | 0.012        | -0.312       | 0.121        |
|        | MMO      | 0.242   | 0.233         | -0.180       | 0.372        | 0.300        | 0.137        |
| Long term | Helkimo Di | -0.250  | 0.895         | -0.50        | 0.792        | -0.45        | 0.811        |
|        | Helkimo Ai | 0.342   | 0.064         | -0.201       | 0.287        | -0.256       | 0.172        |
|        | MMO      | -0.290  | 0.879         | -0.030       | 0.986        | 0.200        | 0.289        |
| All TMJs | Helkimo Di | -0.057  | 0.675         | -0.051       | 0.708        | -0.101       | 0.460        |
|        | Helkimo Ai | 0.103   | 0.448         | -0.018       | 0.898        | 0.227        | 0.092        |
|        | MMO      | 0.181   | 0.182         | -0.334       | 0.012        | -0.249       | 0.064        |

CBCT – cone-beam computed tomography.

### Table 5. Predictive ability of baseline CBCT values on the prognosis.

| Comparison object | Short term | Long term | All TMJs |
|-------------------|------------|-----------|----------|
|                   | r          | P value   | r        | P value | r        | P value |
| Helkimo Di        | -0.079     | 0.702     | 0.051    | 0.787   | 0.028    | 0.840   |
| Helkimo Ai        | -0.185     | 0.366     | -0.390   | 0.033   | -0.302   | 0.024   |
| MMO               | -0.144     | 0.482     | -0.076   | 0.691   | -0.101   | 0.461   |

CBCT – cone-beam computed tomography; TMJ – temporomandibular joint; MMO – maximal mouth opening; Helkimo Di – Helkimo clinical dysfunction index; Helkimo Ai – helkimo anamnestic dysfunction index.

In the present study, in addition to analyzing the treatment effect of intra-articular sodium hyaluronate, there was no association between TMJ changes seen on CBCT evaluation and the clinical symptoms and signs. These findings were in accordance with most of the previously published studies, which used CBCT or X-ray scans to assess the clinical and imaging correlations [13,37,38]. However, Su et al. did find an association between the baseline CBCT scores and the baseline clinical parameters in 240 patients with osteoarthritis of the TMJ [39]. The differences between the findings of the present study and previous studies such as that of Su et al., are difficult to explain, as the method of CBCT evaluation were similar [39]. A limitation of the present study was that it did include a small number of patients (51 patients) from a single center. However, even with a larger study population, and based on the data from the present study, it is unclear whether a larger study population would show any difference in the results.

The latter part of the present study focused on the predictive ability of the baseline CBCT evaluation on the prognosis of patients with osteoarthritis of the TMJ, which has not been undertaken before. The results showed that baseline CBCT score was negatively correlated with the Helkimo anamnestic index (Ai). Therefore, the higher the CBCT score, the more symptom relief the patient will have in the long term. However, a larger, multi-center, controlled study is recommended in future to explore the predictive value of CBCT in the evaluation of patient outcome following treatment for osteoarthritis of the TMJ.

**Conclusions**

The findings of this study showed that the injection of sodium hyaluronate into the superior and inferior temporomandibular joint (TMJ) space could relieve the clinical signs and symptoms of osteoarthritis of the TMJ, but did not reverse or prevent the progression of bony destruction during short-term and long-term follow-up. Also, sodium hyaluronate injection into the superior and inferior TMJ space can be an effective treatment to relieve the clinical symptoms for patients with osteoarthritis of the TMJ.
References:

1. McNeill C. Management of temporomandibular disorders: Concepts and controversies. J Prostheth Dent, 1997; 77: 510–22.
2. Cutroneo G, Piancino MG, Ramieri G et al: Expression of muscle-specific integrins in masseter muscle fibers during malocclusion disease. Int J Mol Med, 2012; 30: 235–42.
3. Caldas W, Conti AC, Janson G, Conti PC: Ocularus changes are secondary to temporomandibular joint conditions: A critical review and implications for clinical practice. J Appl Oral Sci, 2016; 24: 411–19.
4. Rugh JD, Solberg WK: Oral health status in the United States: Temporomandibular disorders. J Dent Educ, 1985; 49: 398–406.
5. Magnusson T, Egermark I, Carlsson GE: A longitudinal epidemiologic study of signs and symptoms of temporomandibular disorders from 15 to 35 years of age. J Orofac Pain, 2000; 14: 310–19.
6. Malia ML, Bonjardim LR, Quintans Jde S et al: Effect of low-level laser therapy on pain levels in patients with temporomandibular disorders: A systematic review. J Appl Oral Sci, 2012; 20: 594–602.
7. Dahstrom L, Carlsson GE: Temporomandibular disorders and oral health-related quality of life. A systematic review. Acta Odontol Scand, 2010; 68: 80–85.
8. Palconet G, Ludlow JB, Tyndall DA, Lim PF: Correlating cone beam CT results with temporomandibular joint pain of osteoarthritic origin. Dentomaxillofac Radiol, 2012; 41: 126–30.
9. Jiang Q, Qiu YT, Chen MJ et al: Synovial TGF-beta1 and MMP-3 levels and their correlation with the progression of temporomandibular joint osteoarthritis combined with disc displacement: A preliminary study. Biomed Rep, 2013; 1(2): 218–22.
10. Tanaka E, Detamore MS, Mercuri LG: Degenerative disorders of the temporomandibular joint: Etiology, diagnosis, and treatment. J Dent Res, 2008; 87: 296–307.
11. Kopp S, Carlsson GE, Haraldson T, Wenneberg B: Long-term effect of intra-articular injections of sodium hyaluronate and corticosteroid on temporomandibular joint arthritis. J Maxillofac Surg, 1987; 45: 929–35.
12. Cauvoti S, Matarese G, Isola G et al: Combined orthodontic-surgical management of a transmigrans mandibular canine: A case report. Angle Orthodontist, 2016; 86: 681–91.
13. De Riu G, Stimolo M, Meloni SM et al: Arthrocentesis and temporomandibular joint disorders: Clinical and radiological results of a prospective study. Int J Dent, 2013; 2013: 790648.
14. Aggarwal VR, Lovell K, Peters S et al: Psychosocial interventions for the treatment of temporomandibular joint disorders. J Prosthet Dent, 1997; 78: 510–22.
15. Januzzi E, Nasri-Heir C, Grossmann E et al: Combined palliative and anti-inflammatory medications as treatment of temporomandibular joint disc displacement without reduction: A systematic review. Cranio, 2013; 31: 211–25.
16. Ling PK, Liang H, He YL, Zhang TM: The application of sodium hyaluronate in joint diseases. Zhongguo Xi Fu Chong Jian Wai Ke Za Zhi, 2002; 16: 1–4 [in Chinese].
17. Tang YL, Zhuo QP, Hu L et al: Effects of intra-articular administration of sodium hyaluronate on plasmaeogen activator system in temporomandibular joints with osteoarthritis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2010; 109: 541–47.
18. Li C, Zhang Y, Li J, Shi Z: Inferior or double joint spaces injection versus superior joint space injection for temporomandibular disorders: A systematic review and meta-analysis. J Maxillofac Surg, 2012; 70: 37–44.
19. Yeung RW, Chow RL, Samman N, Chiu K: Short-term therapeutic outcome of intra-articular high molecular weight hyaluronic acid injection for non-reducing disc displacement of the temporomandibular joint. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2006; 102: 453–61.
20. Cohen MM, Altman RD, Hollstrom R et al: Safety and efficacy of intra-articular sodium hyaluronate (Hyalgan) in a randomized, double-blind study for osteoarthritis of the ankle. Foot Ankle Int, 2008; 29: 657–63.
21. Salik RS, Chang TJ, O’Carra WF et al: Sodium hyaluronate in the treatment of osteoarthritits of the ankle: A controlled, randomized, double-blind pilot study. J Bone Joint Surg Am, 2006; 88: 295–302.
22. Trigkilidas D, Anand A: The effectiveness of hyaluronic acid intra-articular injections in managing osteoarthritic knee pain. Ann R Coll Surg Engl, 2013; 95: 545–51.
23. van den Bekerom MP, Lamme B, Sermon A, Muller M: What is the evidence for viscosupplementation in the treatment of patients with hip osteoarthritis? Systematic review of the literature. Arch Orthop Trauma Surg, 2008; 128: 815–23.
24. Shi Z, Guo C, Awad M: Hyaluronate for temporomandibular joint disorders. Cochran Database Syst Rev, 2003; (1): CD002970.
25. Lee JY, Kim DI, Lee SG, Chung JW: A longitudinal study on the osteoarthritic change of the temporomandibular joint based on 1-year follow-up computed tomography. J Craniofaciofol Surg, 2012; 40: e223–28.
26. Moystad A, Mork-Knutzen BB, Bjornland T: Injection of sodium hyaluronate compared to a corticosteroid in the treatment of patients with temporomandibular joint osteoarthritis: A CT evaluation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2008; 105: e53–60.
27. Schifflman EL, Ohrbach R, Trueove EL et al: The research diagnostic criteria for temporomandibular disorders. V: Methods used to establish and validate revised axis I diagnostic algorithms. J Orofac Pain, 2010; 24: 63–78.
28. Barghan S, Tetradis S, Mallya S: Application of cone beam computed tomography for assessment of the temporomandibular joints. Aust Dent J, 2012; 57: 109–18.
29. 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: 101–21.
30. Gencer ZK, Ozkiris M, Okur A et al: A comparative study on the impact of intra-articular injections of hyaluronic acid, tenoxicam and betamethason on the relief of temporomandibular joint disorder complaints. J Craniofaciofol Surg, 2014; 42: 1117–21.
31. El-Hakim II, Elyamani AD: Preliminary evaluation of histological changes found in a mechanical arthritic temporomandibular joint (TMJ) exposed to an intra-articular Hyaluronic acid (HA) injection, in a rat model. J Craniofaciofol Surg, 2011; 39: e10–14.
32. Tuncel U: Repeated sodium hyaluronate injections following multiple arthrocenteses in the treatment of early stage reducing disc displacement of the temporomandibular joint: A preliminary report. J Craniofaciofol Surg, 2012; 40: 685–89.
33. Li C, Long X, Deng M et al: Osteoarthritic changes after superior and inferior joint space injection of hyaluronic acid for the treatment of temporomandibular joint osteoarthritis with anterior disc displacement without reduction: A cone-beam computed tomographic evaluation. J Maxillofac Surg, 2015; 73: 232–44.
34. Hirota W: Intra-articular injection of hyaluronic acid reduces total amounts of leukotriene C4, 6-keto-prostaglandin F1alpha, prostaglandin F2alpha and interleukin-1beta in synovial fluid of patients with internal derangement in disorders of the temporomandibular joint. Br J Oral Maxillofac Surg, 1998; 36: 35–38.
35. Guo H, Fang W, Li Y et al: Up-regulation of proteoglycan 4 in temporomandibular osteoarthritic synovial cells by hyaluronic acid. J Oral Pathol Med, 2015; 44: 622–27.
36. Liu XM, Cai XY, Yang C et al: Can puncture increase the risk of intra-articular adhesion in the temporomandibular joint? J Craniofaciofol Surg, 2014; 25: e26–29.
37. Mathew AL, Sholapurkar AA, Pai KM: Condylar changes and its association with age, TMD, and dentition status: A cross-sectional study. Int J Dent, 2011; 41:6369.
38. Sato H, Osterberg T, Ahlqvist M et al: Association between radiographic findings in the mandibular condyle and temporomandibular dysfunction in an elderly population. Acta Odontol Scand, 1996; 54: 384–90.
39. Su N, Liu Y, Yang X et al: Correlation between bony changes measured with cone beam computed tomography and clinical dysfunction index in patients with temporomandibular joint osteoarthritis. J Craniofaciofol Surg, 2014; 42: 1402–7.