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Evaluation of temporomandibular joint changes seen in pre-operative and post-operative patients of oral submucous fibrosis using MRI: A prospective study

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ABSTRACT

Purpose: To evaluate alterations in temporomandibular joint due to immobilisation and re-mobilisation in oral submucous fibrosis patients.
Materials and Methods: The study population included 2 groups, patients and normal – 22 TMJ's of 11 individuals respectively. MRI was performed on all patients pre-operatively and 5^{th} month post-operatively and also on controls. Disc thickness (anterior, intermediate and posterior zone), disc length, joint space and structural changes in the glenoid fossa and condylar head were assessed in all the MRI scans. The severity of changes in relation to duration of reduced mouth opening was noted. And, finally regeneration potential of the TMJ after remobilizing the jaw, on 5th month POD was observed. All the measurements were tabulated and subjected to statistical analysis.
Results: The study showed that there were significant differences in the pre-op and normal. The post treatment values/dimensions were comparatively the same as that of the normal population (except for joint space on right side and disc length on left side, which is negligible). It proves that the treatment makes the condition comparably similar to that of normal dimension over a time period of 5 months, sighting the potential capacity of the TMJ to regenerate and repair.
Conclusion: The study revealed statistically highly significant changes in the components of Temporomandibular joint in OSMF patients with varying degrees of restriction in mouth opening when compared to controls, and return of the joint structurally towards recovery at 5^{th} month POD stresses upon the need for an early intervention.

1. Introduction

Oral submucous fibrosis first described in early 1950 is a high-risk precancerous condition.[1] It has a high rate of morbidity because it causes a progressive inability to open the mouth, resulting in eating difficulties and consequent nutritional deficiencies. This Potentially malignant condition causes stiffness of oral mucosa and is expected to cause Temporomandibular joint changes. Trismus is one of the classical and consistent manifestations of oral submucous fibrosis. Trismus for prolonged periods may cause TMJ changes due to disuse. Impaired mouth movements and lack of functional stimuli of TMJ can lead to the joint changes.[2] Immobilization of synovial joints causes structural and functional effects. Lack of physical stimulus affects the homeostasis of the joint. The movement of the joint causes' movement of the synovial fluid and trans- synovial nutrient flow to cartilage and ligaments. Immobilization causes reduced water and glycosaminoglycans content thus causing impaired lubrication.[3] As the mouth opening reduces, there is subsequent narrowing of joint space leading

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to development of joint contractures following four to twelve weeks of decreased mouth opening.[4] Degeneration becomes progressively more severe as the duration of the decreased mouth opening increases.[5] Reparative events begin appearing after 28 days. Although initially decreased mouth opening produces destructive changes these changes are reversible.[6]

Hence, in this study we evaluated the changes in TMJ by performing MRI in OSMF patients pre and post treatment. When decreased mouth opening of duration of 4-12 weeks can cause significant changes in TMJ it becomes necessary to evaluate regenerative changes following the same period of remobilisation or with an additional of 5 more weeks.

2. Materials and Methods

The study was conducted in the Department of Oral, Maxillofacial and Reconstructive Surgery, Bapuji Dental College and Hospital, Davangere. TMJ MRI scanning of all the controls and patients, pre-operatively and post-operatively were done in the Department of Radiology, JJMMC, Davangere. Individuals, who were subjected to MRI scans for reasons other than TMJ disorders and had both TMJs included in their scans served as controls.

2.1. Examination

A systematic case history was recorded and thorough clinical examination of the study population was carried out.

Interincisal opening was measured from the incisal edge of upper incisors to the incisal edge of lower incisors at maximal mouth opening with the help of Digital Vernier calliper. The study Population was divided into 2 major groups namely Group I – any individual subjected to MRI scans for reasons other than TMJ disorders who would have had both TMJs included in their MRI scans and having apparently normal TMJ served as controls and Group II- 22 TMJs of 11 patients who had OSMF (proven clinically and histopathologically according to Khanna et al.) and restricted mouth opening. Individuals satisfying the inclusion and exclusion criteria were taken up for MRI.

2.2. Inclusion criteria

1. Individuals without any history of tobacco or pan chewing.
2. Individuals with mouth opening greater than 35mm.
3. Individuals without any systemic diseases.

2.3. Inclusion criteria

1. Individuals who are clinically diagnosed with oral submucous fibrosis.
2. OSMF patients with complaint of reduced mouth opening for more than 6 months.
3. OSMF patients with reduced mouth opening of lesser than 35mm.

2.4. Exclusion criteria

1. Any other pathological causes which leads to difficulty in mouth opening.
2. Patients with Immunosuppressive drugs (Long term corticosteroid therapy).
3. Debilitating systemic diseases, generalized degenerative joint disease.
4. Drug abuse (Heroin, cocaine, methamphetamine etc.
5. Patients with Immunosuppressive disease (Eg: HIV, AIDS, and Hepatitis C).
6. Individuals with parafunctional habits.
7. Irradiated patients.
8. Pregnant women.
9. Patients with metallic implants, cardiac pacemakers, prosthetic heart valves, aortic stents, cochlear implant.

2.5. Investigations

All patients were subjected to routine and special investigations such as, CBC, RBS, bleeding time, Clotting time, Urea, Creatinine, HbsAg, HIV, SGOT, SGPT, blood group & Rh type. Orthopantamogram, Chest X-ray and ECG were done.

MRI of both the TMJs was performed on a 1.5 Tesla Philips Achieva MR unit by using a 12-channel head coil [(Philips Achieva) (Fig 1, Fig 2)]. T1 [repetition time msec/echo time msec -450 / 90], T2 [repetition time msec/echo time msec – 4362 / 90, slice thickness - 3 mm] and Proton Density (PD) weighted images will be obtained in axial, coronal and oblique sagittal sections. MRI scans were obtained from Department of radiology, JJMMC, Davangere who's TMJs were scanned for reasons other than TMJ disorders and these served as controls. MRI was performed on patients with OSMF pre-operatively and 5^{th} month post-operatively. A section thickness of 3 mm and an intersection gap of 0.3 mm, a matrix of 512 × (305–512), and a field of view of 140–160 mm was used for all the sequences. Oblique sagittal Proton Density weighted images were utilized to evaluate the disc, joint space. Oblique sagittal T1 weighted images for evaluating morphology of the condyles. Imaging was done in closed mouth with the mandible in relaxed position without clenching.

Thickness of the Disc: The thickness of the disc was measured at the level of anterior band, intermediate zone and posterior band on the sections where the discs will be best seen. (Fig 3, Fig 4, Fig 5)

Joint Space: The joint space was measured in sagittal slices from the superior most aspect of the condylar head to the most concave portion of the glenoid fossa. (Fig 6)

Disc Length: Measurements was made on the midsagittal sections where the disc had its maximum length, anteriorly from the junction of anterior band attachment and posteriorly from the junction of posterior band attachment. (Fig 7)

Condyle: Condyle was assessed for bony changes which includes flattening, erosion and advanced degenerative changes.

Glenoid fossa: The fossa was assessed for bony changes which includes flattening, erosion and advanced degenerative changes.

All the patients were assessed and the surgical management was carried out as per the requirement. The surgeries were performed under General anaesthesia and the various procedures that were considered are as follows:

1. Transection of fibrous bands
2. Placement of collagen Membrane with silicone plates
3. Nasolabial flap
4. Coronoidectomy

2.6. Post operative assessment

Irrespective of the surgical procedure followed to rehabilitate the mouth opening, a postoperative MRI was performed in similar fashion as the pre-op on all surgically treated patients on the 5^{th} month post-op day. The collected data was entered in excel software and analysed using R-software 3.2.3. Continuous variable was expressed as mean and standard deviation. Categorical variable was expressed as count percentage. Independent student T test was employed to compare means of 2 groups. The results were considered statistically significant at $p<0.05$.

This project has been reviewed and approved by ethical committee of Bapuji Dental College and Hospital, RGUHS.(2018)

3. Results

The study consisted of 11 male OSMF patients and 11 healthy male controls, whose left and right TMJs were evaluated. The age range for OSMF patients was between 23years to 49years with a mean of 33.4years. The age range of control was between 22years to 54 years with a mean of 28.5 years. On comparing the mean age of controls and OSMF patients there was no significant difference between the groups, i.e, they were comparable and matched.

The grading of mouth opening was based on Khanna and Andrade classification. Maximum interincisal opening of all controls and patients were noted, pre-operatively and 5 months post-operatively.

Patients with mouth opening lesser than 35 mm underwent surgery. An increase in 10mm mouth opening at the end of 5 months was considered a successful surgery. Hence, effect of re-mobilisation of the joint could be further evaluated.

3.1. Thickness of articular disc

Anterior band thickness: The mean value of anterior band thickness on right side pre-operatively and 5 months post-operatively was 2.49mm and 2.97mm respectively with a p value of 0.013. While on the left side the anterior band mean values pre-operatively and post-operatively were 2.45mm and 3.13mm respectively with a p value of 0.003. Whereas the mean value for the control group was 3.27mm and 3.33mm on right and left side respectively. (Table 1)

Intermediate zone thickness: The mean value of intermediate zone thickness on right side pre-operatively and 5 months post-operatively was 1.59mm and 1.70mm respectively with a p value of 0.067. Though on the left side the mean values pre-operatively and post-operatively were 1.59mm and 1.77mm respectively with a p value of 0.13. While the mean value for the control group was 1.68mm and 1.80mm on right and left side respectively. (Table 1)

Posterior band thickness: The mean value of posterior band thickness on right side pre-operatively and 5 months post-operatively was 2.30mm and 2.77mm respectively with a p value of 0.01. While on the left side the anterior band mean values pre-operatively and post-operatively were 2.32mm and 2.91mm respectively with a p value of 0.009. And the mean value for the control group was 2.82mm and 2.89mm on right and left side respectively.

The paired t test was applied and it showed that there was a significant difference in the pre-operative and postoperative dimensions in Band thickness (anterior and posterior band).

Also, Independent samples t test showed that for Anterior band and Posterior band thickness (both right and left side), the pre-operative value for test group patients is significantly different from normal group, whereas after treatment, in the test group, the post-operative dimensions tended to be comparative as that of normal patients' dimensions. (Table 1)

3.2. Disc length

The mean disc length on the right side pre-operatively and 5 months post-operatively was 1.04cm and 1.12cm respectively with a p value of 0.10. While on the left side it was 1.06cm and 1.15cm respectively with a p value of 0.007. The mean value for the control group was 1.06cm and 0.99cm on right and left side respectively. (Table 1)

The paired t test was applied and it showed that there was a significant difference in pre-operative and postoperative dimensions in Disc length on the left side.

3.3. Joint space

The mean joint space on the right side pre-operatively and 5 months post-operatively was 3.17mm and 3.45mm respectively with a p value of 0.12. While on the left side it was 3.42mm and 3.90 mm respectively with a p value of 0.01. The mean value for the control group was 4.23mm and 4.05mm on right and left side respectively. (Table 1)

The paired t test was applied and it showed that there was a significant difference in pre-operative and postoperative dimensions on the left side.

However, on applying Pearson's coefficient test there were no significant changes in the band thickness, disc length and joint space in relation to the duration of reduced mouth opening owing to the small sample size. (Table 2)

Condylar changes: The condylar shape changes were categorised as rounded, angular, flattened and mixed. They were also further divided based on the surface changes into eroded and not eroded. On application of Mc Nemar's Chi-square test there were no significant changes in condylar dimensions pre and post operatively due to small sample size with a p value of 0.06 and 0.31 for right and left side respectively.

Glenoid fossa changes: The Glenoid fossa shape changes were categorised as rounded, angles, flattened and mixed. They were also further divided based on the surface changes into eroded and not eroded. On application of Mc Nemar's Chi-square test there were no significant changes in glenoid fossa dimensions pre and post operatively due to small sample size with a p value of 0.9 and 0.5 for right and left side respectively.

4. Discussion

Mandibular hypomobility is a common sign in patients suffering from temporomandibular disorders as well as a variety of pathologies of the masticatory system. The causes of mandibular hypomobility are multiple and can be related to intra-articular or extra-articular conditions.[7]

Thinning of articular disc and perforation of the disc is noted due to excessive and long-term loading of the joint, under the conditions of the closed mouth and the dental contacts. The constant excessive pressure in that zone can lead to perforation of the disc.[8]

Trismus is one of the classical manifestations of OSMF due to accumulation of inelastic fibrous tissue in the juxta epithelial region of oral mucosa with associated muscle degeneration. Progressive restriction in movement of the joint secondary to OSMF and a deficient functional stimulation of TMJ leads to reduced efficiency of the temporomandibular joint.[5]

Lack of mobilization has profound effects on the temporomandibular joint and contributes significantly to the pathogenesis of temporomandibular joint disease. The restoration of temporomandibular joint mobility has profound effects on the maintenance and integrity of cartilage and synovial tissues.[7]

Immobilization, whether prescribed as a form of treatment or as a pathological condition, has been recognized clinically in humans and experimentally in animals as having detrimental effects on bone and soft tissue homeostasis. Changes include mechanical, histological and biomechanical alterations.[9] Therefore, efforts are introduced to increase joint mobility, such that fluid dynamics begin to improve. Rehabilitation uses the principles of active and passive motion and decreased joint loading. The chief function of rehabilitation is confined to the direct effects on intra-articular structures.[9]

Hence the present study was carried out to determine the temporomandibular joint changes in OSMF patients with varying duration of limited mouth opening. MRI was used to assess the disc thickness, disc length, joint space, condylar head and glenoid fossa changes pre-operatively and 5 months post-operatively. The same measurements were done on healthy individuals who were taken as controls for an evidence-based study.

The meniscus accommodates the hinging action as well as the gliding motion that occurs between the temporal bone and the mandible. A lot of studies have shown morphologic changes in the disc.[7,10–12] One important function of the disc is to compensate for the differences in shape between the articular surfaces of the condyle and the temporal components of the TMJ, the fossa and the articular eminence. Therefore, it is possible for the disc to adjust its shape to fit the changes in joint space associated with osseous remodelling of the TMJ that often occurs in response to changes in occlusion. Our results showed significant changes in the right and left anterior and posterior band thickness when compared pre-operatively and 5 months post-operatively. Also, each of these measurements were compared with that of control and significant difference were observed. It proves that the treatment makes the condition comparably similar to that of normal dimension over a time period of 5 months. But intermediate zone showed no significant changes. Immobilization creates excessive fatty fibrous connective tissue which forms mature scars and creates intra-articular adhesions. Restricted range of motion due to capsular fibrosis creates a distinct reduction in the blood supply to the joint capsule. Capsular tightness causes improper loading of articular cartilage. Capsular tightness will cause certain areas of the articular cartilage to receive higher impact loads, possibly leading to fatigue and degenerative changes.[9]

Only 1 study was conducted to study the disc thickness in detail diving it into 3 parts, namely, the anterior band, intermediate zone and the posterior band. Their thickness changes were evaluated in healthy controls and patients affected with OSMF. The authors found significant

Table 1: Distribution of control group vs pre and post of test group values

Variable	Side	Group	Mean	SD	SEM	p value
Anterior Band Pre-op	Right	Test	2.4900	.24984	.07533	0.001
		Control	3.2730	.28496	.09011	
Anterior Band Post-op	Right	Test	2.9727	.42221	.12730	0.07
		Control	3.2730	.28496	.09011	
Anterior Band Pre-op	Left	Test	2.4518	.23073	.06957	0.001
		Control	3.3370	.27580	.08722	
Anterior Band Post-op	Left	Test	3.1327	.44571	.13439	0.22
		Control	3.3370	.27580	.08722	
Posterior Band Pre-op	Right	Test	2.3045	.38360	.11566	0.02
		Control	2.8220	.59142	.18702	
Posterior Band Post-op	Right	Test	2.7700	.44276	.13350	0.80
		Control	2.8220	.59142	.18702	
Posterior Band Pre-op	Left	Test	2.3255	.49754	.15001	0.03
		Control	2.8910	.13820	.04370	
Posterior Band Post-op	Left	Test	2.9136	.35525	.10711	0.82
		Control	2.8910	.13820	.04370	
Disc Length Pre-op	Right	Test	1.0473	.08284	1.0473	0.73
		Control	1.0660	.16249	1.0660	
Disc Length Post-op	Right	Test	1.1209	.12284	1.1209	0.39
		Control	1.0660	.16249	1.0660	
Disc Length Pre-op	Left	Test	1.0627	.09264	1.0627	0.13
		Control	.9980	.09953	.9980	
Disc Length Post-op	Left	Test	1.1564	.10414	1.1564	0.002
		Control	.9980	.09953	.9980	
Joint space pre-op	Right	Test	3.1791	.40979	.12356	0.001
		Control	4.2370	.33977	.10745	
Joint space post-op	Right	Test	3.4564	.45120	.13604	0.001
		Control	4.2370	.33977	.10745	
Joint space pre-op	Left	Test	3.4236	.42309	.12757	0.001
		Control	4.0540	.44320	.14015	
Joint space post-op	Left	Test	3.9064	.25410	.07661	0.35
		Control	4.0540	.44320	.14015	
Intermediate Zone Pre-op	Right	Test	1.5936	.22380	.06748	0.51
		Control	1.6810	.36961	.11688	
Intermediate Zone Post-op	Right	Test	1.7064	.38019	.11463	0.87
		Control	1.6810	.36961	.11688	
Intermediate Zone Pre-op	Left	Test	1.5945	.29032	.08754	0.15
		Control	1.8020	.34918	.11042	
Intermediate Zone Post-op	Left	Test	1.7736	.44927	.13546	0.87
		Control	1.8020	.34918	.11042	

Table 2: Assessment of severity of changes in relation to duration of reduced mouth opening

Duration vs	Anterior band R	Anterior band L	Posterior band R	Posterior band L	Inter band R	Inter band L	Disc Length R	Disc Length L	Joint space R	Joint space L
r	-.098	.168	-.108	.045	.139	.478	.366	-.063	-.108	-.093
P value	.775	.622	.751	.896	.684	.137	.269	.854	.752	.786
Interpret–action	Insignificant		Insignificant		Insignificant		Insignificant		Insignificant	

r =Pearson's correlation coefficient

changes.[5]

Authors suggested the important role of motion in rehabilitation of patients with mandibular hypomobility. They studied the gross and microscopical changes associated with prolonged immobilisation which included proliferation of fibro fatty connective tissue into the joint space and obliteration of joint space.[7] In our study we found similar gross changes where in the joint space was reduced in the OSMF patients when compared to the controls and upon treatment there was rehabilitation of the joint. In a study conducted on rat knee joints it was noted that connective tissue proliferated and caused adhesions and vascular engorgement and was particularly more with longer durations of immobilisation.[13]

Significant changes in the disc length were observed in our study. The length was reduced in the pre-operative condition when compared to the healthy controls and also, they increased minimally upon observation after 5 months post-operatively. In comparison to a study that found significant reduction in disc length in association with decreased mouth opening when compared with controls.[5]

It is believed that the remodelling of the load-bearing joints is an important adaptation process needed for appropriate stress distribution and function. It has been recognized that, both progressive and regressive, mechanically-induced remodelling is a normal process early on. When the capacity for the joint to remodel has been exceeded, remodelling merges into osteoarthritis. Characteristic osteoarthritic changes observed in the TMJ include alterations in shape and overall size of joint components, specifically, flattened fossa, less pronounced articular eminence, decreased condylar volume and thickened disc. Degenerative remodelling present in pathologic TMJs may result from either decreased adaptive capacity in the articulating structures or from excessive or sustained physical stress to the articulating structures.[14]

Our study showed no significant changes in the condylar shape and surface changes, likewise no changes were observed in the glenoid fossa. However, the shapes were classified according to the study performed on human skulls. According to another study, it has been observed that there are bony changes in terms of generalised osteoporosis of cancellous and cortical bone due to prolonged immobilisation of rat knee joints.[8,15] Some investigators evaluated changes in TMJ anatomy through MRI in patients with disc displacement and found a substantive change and a direct correlation.[16]

A definite correlation to structural changes with duration of reduced mouth opening was noted in all the cases but statistically significant results were not obtained due to small sample size. However, in a study performed on rabbit TMJ concluded that degeneration becomes progressively more as the duration of immobilisation increased.[17] Also, according to some other investigators who experimented on rat knees and made a note of gross and microscopic changes also saw worsening of degenerative changes with increased immobilisation.[3] Mobility dysfunction, whether acute or chronic, will inhibit lymphatic clearing. An inflammation-oedema cycle can easily develop and will further contribute to degenerative joint breakdown, adhesion formation, capsular fibrosis, and other responses.[9]

In our study one of the cases showed further reduction in mouth opening with equally worsening TMJ parameters. An investigator recognised that "the reproductive powers of cartilage are very limited", and that injuries to joints “are backward in their cure.”

The temporomandibular joint (TMJ), however, is remarkable for its capacity to regain normal function even after the fibrocartilaginous articular surface of the condyle is severely disrupted. Cartilaginous healing in the TMJ has been noted previously in experimental animals, mostly immature rodents, after various ablative procedures to the articular surface of the mandibular condyle. The pattern of repair in subhuman primates, particularly in adult animals, has presented a mixed picture of fibrous tissue replacement with some areas of chondrification. However, no study to date has examined in detail the components in the matrix comprising articular surface repair in the TMJ.[18]

This can be a stepping stone towards understanding the effect of OSMF on TMJ. As some of the authors also concluded that there is a potential for healing if the basic matrix structure remains intact and enough viable cells remain, the cells can restore the normal tissue composition. Also, depending on the location and size of the lesion and the structural integrity and alignment of the joint, the lesion may or may not progress to cartilage degeneration.[19] Hence there is a need for an early surgical intervention in management of OSMF along with active physiotherapy to break the chain of events that result in destruction of the joint and help rehabilitate it.

5. Conclusion

The results of our study suggested that there are definite TMJ changes with respect to the band thickness and the joint space. A positive change was noted from pre-operative conditions to that of the post-operative conditions, correspondingly a significant transformation was noted from healthy controls to the pre-operative patients with OSMF. Also, variations in the morphology of the condyle and the glenoid fossa were noted when healthy individuals were compared with that of pre-operative patients. However, for a statistically significant result to be obtained for correlation of duration of reduced mouth opening with TMJ changes our sample size was small. It can be safely said that an early intervention in mobilising the joint will help in restoring of the form and function by substantially reversing the structural changes in a relatively short period of time.

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None declared.

7. Conflict of Interest

None declared.

References

1. Dyavanagoudar SN. Oral Submucous Fibrosis: A Review on Etiopathogenesis, Diagnosis, and Therapy. *J Cancer Sci Ther*. 2009;1(2):72–7.
2. Masthan K, Babu A, Shankari L, Gayathiri K. Oral Submucous Fibrosis: A forerunner of TMJ changes. *Bisci Biotech Res Asia*. 2013;10(1):261–5.
3. Akeson WH, Amiel D, Abel MF, Garfin SR, Woo SL. Effects of immobilization on joints. *Clin Orthop Relat Res*. 1987;219:28–37.
4. Akeson WH. An experimental study of joint stiffness. *J Bone Joint Surg Am*. 1961;43A:1022–34.
5. Nanthini C, Sathasivasubramanian S, Arunan M. Temporomandibular joint changes in oral submucous fibrosis- A magnetic resonance imaging study. *J Clin Exp Dent*. 2018;10(7):673–80.
6. Poremba EP, Moffett BC. The effects of continuous passive motion on the temporomandibular joint after surgery: Part I. Appliance design and fabrication. *Oral Surg Oral Med Oral Pathol*. 1989;67(5):490–8.
7. Israel HA, Syrop SB. The important role of motion in the rehabilitation of patients with mandibular hypomobility: a review of the literature. *Cranio*. 1997;15(1):74–83.
8. Ivkovic N, Racic M. Structural and Functional Disorders of the Temporomandibular Joint (Internal Disorders). In: Almasri M, Kummoona R, editors. Maxillofacial Surgery and Craniofacial Deformity; 2018. p. 1–26. doi:10.5772/intechopen.81937.
9. Mccarty WL, Darnell MW. Rehabilitation of the temporomandibular joint through the application of motion. *Cranio*. 1993;11(4):298–307.
10. Tomas X, Pomes J, Berenguer J, Quinto L, Nicolau C, Mercader JM, et al. MR imaging of temporomandibular joint dysfunction: a pictorial review. *Radiographics*. 2006;26(3):765–81.
11. Kreutziger KL, Mahan PE. Temporomandibular degenerative joint disease. Part I. Anatomy, pathophysiology, and clinical description. *Oral Surg Oral Med Oral Pathol*. 1975;40(2):165–82.
12. Moncada G, Cortés D, Millas P, Marholz C. Relationship between disk position and degenerative bone changes in temporomandibular joints of young subjects with TMD. An MRI study. *J Clin Pediatr Dent*. 2014;38:269–76.
13. Evans EB, Eggers GW, Butler JK, Blumel J. Experimental immobilization and remobilization of rat knee joints. *J Bone Joint Surg*. 1960;42(5):737–58.
14. Murphy MK, Macbarb RF, Wong ME, Athanasiou KA. Temporomandibular disorders: a review of etiology, clinical management, and tissue engineering strategies. *Int J Oral Maxillofac Implants*. 2013;28(6):393–414.
15. Ribeiro EC, Sanches ML, Alonso LG, Smith RL, Ribeiro E, Sanches M, et al. Shape and symmetry of human condyle and mandibular fossa. *Int J Odontostomat*. 2015;9:65–72.
16. Robinson PD. Articular cartilage of the temporomandibular joint: can it regenerate. *Ann R Coll Surg Engl*. 1993;75(4):231–6.
17. Lydiatt DD, Davis LF. The effects of immobilization on the rabbit temporomandibular joint. *J Oral Maxillofac Surg*. 1985;43(3):188–93.
18. Braun BL. The effect of physical therapy intervention on incisal opening after temporomandibular joint surgery. *Oral Surg Oral Med Oral Pathol*. 1987;64(5):544–8.
19. Buckwalter JA. Articular cartilage: injuries and potential for healing. *J Orthop Sports Phys Ther*. 1998;28(4):192–202.

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