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Magnetic resonance imaging and clinical evaluation of the temporo-mandibular joint after mandibular reconstruction

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Abstract---The aim of this retrospective study was to assess, clinically and by MRI the short and long term effect of unilateral mandibular segmental repair by reconstruction plate on the ipsilateral and contralateral TMJ. 18 adult patients (12 male & 6 female) with history of mandibular reconstruction by titanium reconstruction bone plate were included. The age range was 32-66 years (mean 49years). The condyle in the reconstruction side was preserved. Based on the follow up period following the reconstruction, three groups were established. Magnetic resonance imaging was performed for all patients at the recommended follow up periods. Clinical examination also was done for all the patients in the same intervals. The result of this study

demonstrated that there were no statistically significant differences noted between the three groups regarding the clinical data and also there were no significant differences between the MRI findings in all groups.

Keywords---magnetic resonance imaging, clinical evaluation, temporo-mandibular joint, mandibular reconstruction.

Introduction

Mandibular defects requiring reconstruction are common and may result from resection of benign or malignant lesions, trauma, or osteoradionecrosis⁽¹⁾. Following resection, the patient would be left with significant hard and soft tissue deficits, which requires reconstruction not only to replace the missing structural component, but also to restore the associated function. This restoration of form and function becomes increasingly difficult as the resected become larger and complex in nature⁽²⁾. Simplicity of procedure, intact facial function, and esthetic outcome with the least possible donor site morbidity are the minimum requirements of a good reconstruction. Despite being challenging for head and neck reconstructive surgeons, oro-mandibular reconstruction, is now reliable and highly successful, with excellent long-term functional and aesthetic outcomes⁽³⁾. Although there are many different reconstructive options⁽⁴⁾, reconstruction plates are simple to use, commercially available, allow rapid resumption of oral function, and eliminates the need for maxilla-mandibular fixation (MMF) in cases of delayed reconstruction⁽⁵⁻⁷⁾.

Options in plate selection include mandibular reconstruction plates, miniplates, and locking plates, all of which are available in titanium and stainless steel^(5,9,10). Titanium plates are more biocompatible and mechanically similar to bone than other metals; thus, they are not required to be removed after graft healing. The primary goal of mandibular reconstruction is to achieve restoration of bony contour, lining of intraoral contents, and preserved masticatory function. In particular, it is essential to preserve function at the temporomandibular joint (TMJ) to allow for adequate mandibular mobility and mastication and to mitigate trismus or dislocation. TMJ malposition after trauma, reconstruction, or orthognathic surgery can result in TMJ pain, clicking, or malocclusion. TMJ ankylosis also can develop, requiring future surgeries to correct^(1, 11).

The recent advance of rapid prototype technology in the engineering field has led to the production of prototype parts and models from computerized imaging. Medical rapid prototyping (MRP) is defined as the manufacture of dimensionally accurate e physical models of human anatomy derived from medical image data using a variety of rapid prototyping technology⁽¹²⁾. Prebent plate fixation using a 3-dimensionally corrected, real-sized plastic bone model prepared by preoperative computer simulation is a precise and relatively easily performed technique that results in satisfactory clinical outcome⁽¹³⁾. Therefore, the purpose of this retrospective study was to assess, clinically and by MRI the short and long term effect of unilateral mandibular segmental repair by reconstruction plate on the ipsi-lateral and contralateral TMJ.

Patients and Methods

Study Design and Population

To address the research purpose, a retrospective study was designed and performed. The study population was composed of 18 patients (6 females & 12 males) Age range 32-66 (mean $49 \pm$ SD) who presented to the oral and maxillofacial surgery department in the International Medical centre in Cairo - Egypt, between January 2015 to August 2017 for the evaluation and management of segmental mandibular defect secondary to mandibular neoplasm in 12 cases (4 cases osteomyelitis and 2 cases osteoradionecrosis)

Patients who fulfilled the following inclusion criteria were included in the study:

1. Patients with unilateral mandibular segmental defect
2. Condyle of the mandible should be left at the resection
3. Presence of postoperative MRI
4. Patients should be free from any TMJ disorders or joint surgery

Patients were excluded from the study if they had one of the following conditions:

5. Patients with a resection affecting the condyle
6. Patients with incomplete clinical and MRI records
7. If the patient had systemic or local disorders that may affect the joint.

In accordance with the declaration of Helsinki, written informed consent was obtained from all patients the local ethics review committee of International Medical Centre approved the study. Demographic variables included age, gender and the site of the segmental defect.

The patients were divided into three groups based on the duration of the follow up period:

Group one: patients were followed for year Group two: patients were observed for three years

Group three: patients were assessed for five years.

Treatment Protocol:

Preoperative preparation: preoperative diagnosis was made clinically, orthopantomogram and CT.

Surgical procedures

The method of mandibular reconstruction involved the use of pre bent metal reconstruction plate. Basic data used for virtual planning included preoperative CT scans, The scan data were imported, as DICOM standard files, to surgical simulation software for reconstruction of the 3D virtual model. At first, the cutting tool provided in the software was used to remove a diseased portion and a remnant mandibular image was portrayed. The virtual models were built using the mirroring tools of the software; the models were used for preoperative bending of the conventional reconstruction plates to bridge the prospective mandibular

defects. The finished plates were subjected to autoclave sterilization before surgery.

All surgical procedures were performed under general anesthesia, by the same oral and maxillofacial team. All patients underwent segmental mandibular resection and reconstruction with titanium plates. Before surgery, Inter-maxillary fixation was performed to maintain occlusion during reconstruction through extra-oral incision. The mandible was approached. Case should be followed during segmental resection. Before resection, the osteotomy cuts were traced on the mandible. The plate was temporarily fixed with screws. Then the plate was removed and the resection was completed. The plate was finally fixed according to the pre-existing screw hole with three (2.4mm) titanium bi-cortical screws on the distal and proximal segments. The incisors was sutured with 3/0 Vicryl then the IMF was released to check the occlusion

Postoperative Assessment

The patients were evaluated clinically every week for the first month, then monthly for the first year, then at three and five years following the surgery. The clinical parameters included: malocclusion, facial contour, maximum inter-incisal opening headache, presence of deviation or deflection when opening the mouth, Pain during opening and closing the jaw and chewing.

The patients were asked to score the pain between 0 and 10 according to its severity as follows:

1-3: No pain, 4-6: mid pain, 6-8: moderate pain, 8-10: sever pain.

Presence of TMJ sounds (clicking, crepitation), Presence of pain in masticatory muscles during palpation.

Postoperative complications including: infection, wound dehiscence, plate exposure, facial nerve and inferior alveolar nerve injuries were also recorded.

Radiographic examination:

The surgical site was evaluated Orthopantomogram and CT if indicated.

MRI analysis:

MRI was performed for all patients immediately post-operative, one year, three years and at five years.

All MRI were performed using 1.5 Tesla superconducting (Magnetom H15 SP; Siemens, Erlangen, Germany) both TMJ were imaged using a bilateral surface coil 20 cm in diameter within the surface coil holder. Items that could interfere with the magnetic resonance examination were checked. All patients underwent imaging in the sagittal plane approximately 1.5 cm deep to the skin surface anterior to the tragus of the ear. Multiple sagittal slices with an image thickness of 2 mm were obtained. T1-weighted images were acquired with a spin echo technique (crepitation time of 660 ms, echo delay time of 15 ms and filled of view of 200 mm). The imaging was repeated in the open mouth position applying the same parameters in patients who were able to sustain this position.

Image analysis

Anterior disc displacement

The 1st step was evaluation of the disc location in both closed and open-mouth positions relative to the condyle and articular eminence. ADD was assessed in sagittal oblique plane in both closed and open-mouth positions and coronal plane in closed mouth position.

Degenerative changes

TMJ osteoarthritis was diagnosed when more than one of the following changes were noted; fattening of the articular surface, subcortical sclerosis or cyst, surface erosion, osteophytes, and generalized sclerosis for the condylar head and flattening of the articular eminence, subcortical sclerosis, and surface erosions for the fossa. Pulse sequence included sagittal oblique T2 weighted images and proton density close and open mouth positions. The statistical analysis was performed using Microsoft office 2013 (Excel) and IBM SPSS statistics version 20.0 (IBM corp., Armonk, NY, USA). The level of significance was set at $P \leq 0.05$. The X^2 test was used to compare values between groups.

Results

Eighteen patients who fulfilled the inclusion criteria were involved in the study. The age range was from 32-66 years (mean 49 years): 6 females and 12 males. , giving a female to male ratio (1:2). The main cause of the resection was mandibular aggressive benign neoplastic lesions (12 patients) osteomyelitis (4 cases) and osteoradionecrosis (2 cases). All patients were immediately reconstructed with pre-pent reconstruction plates.

Post-operative evaluation

None of the patients had any major post-operative complications, except: four cases who suffered from facial Nerve injury (temporal branch). Resolution of the injury had cured 3 months later and three patients who suffered from wound dehiscence and infection; they were treated with Incision and drainage, antibiotics, routine wound care and packing. The wound healed by secondary intension without further complications within two weeks. All patients were satisfied with their facial contour except two cases who suffered from facial asymmetry due to lower jaw deviation. Elastics were put for two weeks to manage these cases. Extra-oral scars were observed in 3 patients.

Evaluation of post-operative occlusion

All patients showed stable occlusion without premature contact or cross bite except one case who suffered from premature occlusal contact on the non-affected side and the occlusion was corrected with spot grinding.

Post-operative headache

All patients were asked if they had temporal headache during the follow up period. Headache was reported by five cases (four females and one male) immediately post-operative and remained for seven days and responded to NSAIDs.

Maximum inter-incisal Opening (MIO)

In all patients the preoperative MIO ranged between 35 to 45mm (mean 40±1). MIO was significantly decreased post-operatively from one to seven days. The mouth opening was improved gradually that reached its maximum value at six months post operate mouth opening was improved gradually that reached its maximum value at six months post-operative without significant difference than the preoperative values.

Presence of deviation when opening the mouth

Minor mandibular deviation was observed in two cases. However, one case suffered from mandibular deviation with premature occlusal contact. The deviation was corrected by light elastics for two weeks.

Pain during opening and closing the jaws and chewing

Pain was observed in five cases at the same side of surgery and remained for five weeks post operatively. The patients were improved gradually at the third months post operatively.

Presence of TMJ sounds

No patients were suffered from any TMJ sounds during the follow up period. Presence of pain in masticatory muscles during palpation: Only two cases complained from muscle pain after surgery and they had been improved by the use of muscle relaxants and analgesics seven days postoperatively.

Masticatory Muscles

All the muscles of mastication were tender upon palpation immediately post operatively. Muscles tenderness has responded successfully to muscle relaxant and NSAIDs. All patients were improved gradually within two weeks.

Maximum inter-incisal opening (MIO):

The oral opening has been evaluated preoperatively, seven days postoperatively, one year, three years and five years after the reconstruction. MIO reached almost its normal value after 1 year of surgery and remained stable without change all over the follow up period of the study.

Pain

Pain was evaluated by the visual analogue scale as

0	No pain
1-3	Mild pain
4-7	Moderate pain
8-10	Sever pain

Results revealed that there was no significant value difference between pain score at the different follow up periods.

Joint sound

In all the patients of the study there was no abnormal joint sound neither clicking nor crepitation during all the follow up periods.

MRI Results

Regarding the MRI findings, all the patients had no abnormal disc position except two patients had anterior disc displacement with reduction and one patient have developed disc displacement without reduction. By the use of muscle relaxants, analgesics and occlusal splints, all the patients have improved within three months postoperatively.

MRI changes in both TMJ's following reconstruction in the three groups are described in (Table: 1)

MRI Finding	Group 1	Group 2	Group 3
The meniscus	Normal location in both sides	Normal in both sides	No abnormalities in both sides.
The condylar head	Normal translation	Normal translation	Normal translation
Joint effusion	Present	Minimal	No
The lateral pterygoid muscle	Normal	Normal	Normal
Retro-discal tissues	Intact	Intact	Intact
Osteoarthritic changes	No	No	No

From table (1) we could conclude that there was no significant difference regarding the MRI findings in all the study groups. No morphological or articular surface changes were observed in the TMJ at the different follow up periods of the study.

Statistical analysis

Anova test was used to compare between the groups of the study; table 1 showing the statistical results of MIO that indicated that there was a significant difference between the groups ($P > 0.05$). By applying the multiple comparison test (L.S.D) to compare between each two groups we found that there was no significant

difference between group 1 (one year follow up) and group 2 (3 years follow up), while there was a significant difference between group 1 and group 3 (5 years follow up).

Table (2): Statistical results of MIO of the three groups (Anova test)

MIO	Mean	SD	Anova test value (F. value)	P Value
Group 1 (1 year follow up)	39.55	2.66	4.408	.017
Group 2 (3 years follow up)	39.88	2.494		
Group 3 (5 years follow up)	41.66	1.571		

Table (3) comparison between each two groups of the study (L.S.D test)

	Comparison	P Value	Validity
Group 1 (1 year follow up)	group 2	0.665	Non-significant
	group 3	0.008	Significant
Group 2 (3 years follow up)	group 1	0.665	Non-significant
	group 3	0.024	Significant
Group 3 (5 years follow up)	group 1	0.008	Significant
	group 2	0.024	Significant

Regarding the pain score, and by applying Anova test between the groups and L.S.D test between each two groups, it was approved that there was no significant difference regarding pain between the three groups or between each two groups.

Table (4): statistical results regarding pain score in the three groups (Anova test)

MIO	Mean	SD	Anova test value (F. value)	P Value
Group 1 (1 year follow up)	1.6	0.06	6.509	0.102
Group 2 (3 years follow up)	1	0.04		
Group 3 (5 years follow up)	0.3	0.01		

Table (5) comparison between each two groups of the study (L.S.D test)

	Comparison	P Value	Validity
Group 1 (1 year follow up)	group 2	0.102	Non-significant
	group 3	0.213	Non-significant
Group 2 (3 years follow up)	group 1	0.304	Non-significant
	group 3	0.352	Non-significant
Group 3	group 1	0.408	Non-significant

(5 years follow up)	group 2	0.416	Non-significant
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Table (4) and (5) showed the statistical results regarding pain score of the study.

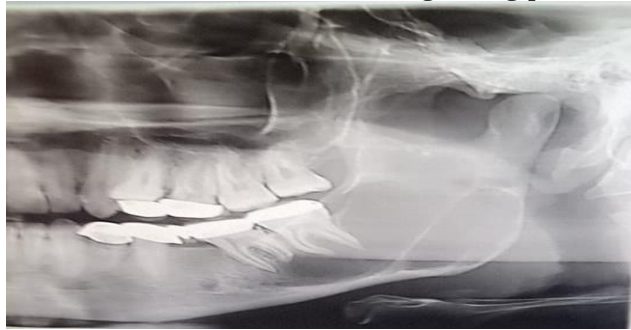


Figure (1): Mandibular Ameloblastoma

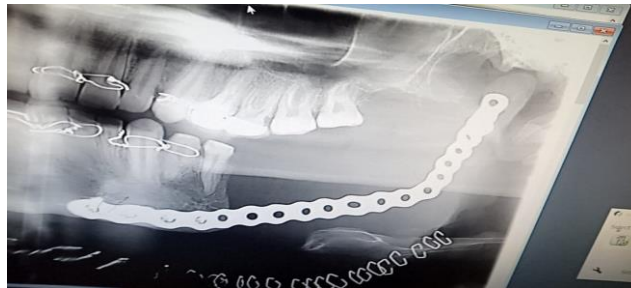


Figure (2): Titanium Bone Plate

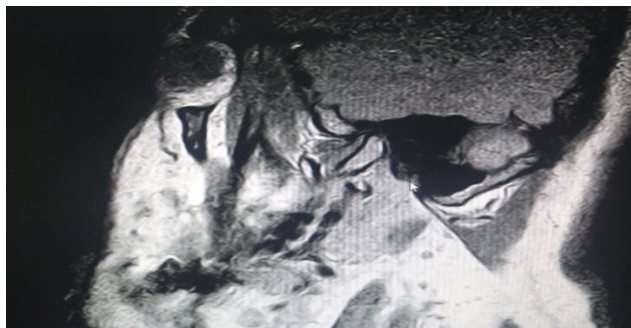


Figure (3): MRI after one year; showing normal TMJ

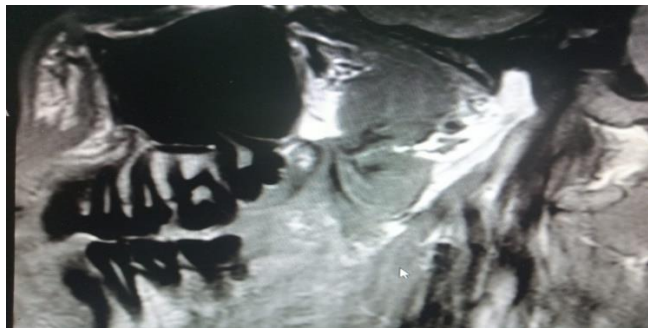


Figure (4): MRI after five years; showing normal TMJ

Discussion

The mandible is an important structure in the maxillofacial area, It plays a significant role in pronunciation and organization of the lower facial contour ⁽¹⁴⁾. Resection of the mandible in oral cancer, trauma, Osteoradionecrosis and sever osteomyelitis, may result in large mandibular defects ⁽¹⁵⁻¹⁷⁾. Reconstruction of the mandibular defect is very important to restore the function, esthetics, and improve the patient quality of life ⁽¹⁸⁾. The choice of reconstruction options for extensive defects remains controversial. It may include the use of osteo-cutaneous free flaps (OCFF), fibular free flaps (FFF) or deep circumflex iliac artery. ⁽¹⁹⁻²¹⁾. Also reconstruction plates have been used for mandibular repair ⁽⁵⁾. Seong et al ⁽²²⁾ evaluated the effect of OCFF, DCIA and FFF on the TMJ after mandibular reconstruction and reported a significant condylar displacement in cases of FFF more than OCFF and DCIA. In addition, DCIA was superior to FFF in condylar position and stability after six months of healing and had advantageous dimensions for the reproducibility of the 3D surgical guides for mandibular reconstruction

Kang et al ⁽¹¹⁾ conducted a study on the effect of mandibular reconstruction by reconstruction plate on TMJ and found sever condylar displacement and fracture of the mandibular bone plate after 6 months of surgery. They explained that the displacement of the condyle may occur as healing progresses between bone segments. Moreover, the force generated by mandibular function induces bone movement that bonds and breaks the metal plate and causing sever condylar displacement. On the contrary to Kang et al, Chao et al ⁽²³⁾ have documented that the standard treatment of mandibular reconstruction is the use of titanium reconstruction plate with locking screws, which provide better biocompatibility and biomechanical improvement.

In the present study, radiological and clinical evaluations have been done after mandibular reconstruction by titanium bone plate. On reviewing the clinical results which include MIO, the joint sounds, the joint pain, we observed that there is no statistically significant differences between the patients at the different follow up periods and all of them nearly resembling the standard measurements of the normal joints. Except for the maximum inter-incisal opening which showed significant improvement in measurement regarding group 3 (five years follow up) in comparison to group 1 and group 2 (one and three years follow up respectively). The same results are reported by many authors ^(24, 25) and the cause was the integrity of the coronoid and condylar process during the resection and reconstruction of the mandible.

It was found that there is no condylar displacement in all the study groups, those result were in agreement with the results of Han et al ⁽²⁶⁾. Who concluded that semi-rigid fixation after mandibular osteotomy provides micro-movements between bone segments to allow functional adjustment of the condylar position. Also, in our study there are no fractures of the reconstruction bone plates in all patients, these results are in contrast to the study of Kang et al ⁽¹¹⁾. The use of MRI gives insights into the changes which may happen to the TMJ secondary to mandibular reconstruction. The results of the present study showed that there is no changes in the structural elements of the TMJ in both sides in all patients,

which may be attributed to the preservation of the two condyles in all the patients in the same side of the reconstruction and also in the contralateral side. These findings are in agreement with the study done by Masataka et al 2019 ⁽²⁷⁾.

MRI has been reported to be 95% accurate in assessment of disc position and 93 % successful in detecting any osseous changes ⁽²⁸⁾. Virtual planning help us in this study to successfully understand the steps of reconstructive procedure, thus achieving an optimal reconstruction of the mandibular defects as also reported by Gil et al ⁽²⁹⁾. Choi et al⁽³⁰⁾ stated that when using prototyping models for preoperative adaptation of reconstruction plates can provide adequate post-operative results as reported in our study showed normal morphology of the TMJ due to proper adaptation of plate on the resected mandible.

Conclusion

In the present study, Pre-bent titanium metal reconstruction plates achieve acceptable results after resection of the mandible regarding the clinical outcome after surgery and preservation of the normal morphology of the TMJ.

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