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ORIGINAL ARTICLE

Reconstruction plate-related complications in mandibular continuity defects

Salwan Yousif Hanna Bede[1] · Waleed Khaleel Ismael[2] · Ehssan Ali Hashim[2]

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Abstract

Purpose The purpose of this study was to evaluate the complications associated with the use of reconstruction plates with or without non-vascularized bone graft in reconstruction of mandibular segmental defects caused by trauma and tumor resection and to analyze various factors that are associated with the development of complications.

Methods A retrospective observational study was conducted, and the investigated variables included the age and gender of the patients, etiology of the defect, the site of the defect, the size of the defect, whether bone graft was used or not, type of plate used, and whether the reconstruction was immediate or delayed. The outcome variables were the postoperative complications and the success rate.

Results Fifty-one patients were enrolled in this study; the etiology of mandibular defect was trauma in 39 patients (76.5%) and resection of benign or malignant tumors in 12 patients (23.5%). The complication rate was (58.8%) and the success rate was (94.1%); the only factor that significantly increased the incidence of postoperative complications was the size of the defect.

Conclusion Reconstruction plates demonstrated a high success rate despite the high complication rate. Segmental defects caused by trauma were smaller than those created after tumor resection and the only factor that increased complication rate was the size of the defect; other factors did not affect the complication rate.

Keywords Complications · Mandibular continuity defects · Reconstruction of mandible · Reconstruction plate

Introduction

The mandible has a complex three-dimensional structure with a central esthetic and functional role [1], and it is the only movable load-bearing bone of the skull that needs to withstand the forces transmitted during function [2]. Acquired mandibular defects, which may result from trauma, infection, or ablative surgery, cause profound disabilities of mastication and swallowing in addition to poor speech and oral incompetence, and they also have a negative effect on facial appearance [3].

There are two major types of mandibular defects, marginal and segmental, marginal defects involve the alveolar portion of the bone with an intact inferior or posterior mandibular border maintaining mandibular continuity, whereas segmental defects are characterized by the presence of mandibular discontinuity (continuity defects) [1].

Many classifications for mandibular defects have been suggested; Brown et al. [4] reported that the (HCL) classification introduced by Jewer et al. [5] is the most widely cited in the literature. The (C) represents central defects involving both canines, the (L) represents lateral defects excluding the condyle, while the (H) represents the hemimandibular defects including the condyle; therefore, eight possible types of mandibular defects can be encountered, namely C, L, H, LC, HC, LCL, HCL, and HH [6].

Among the available options of reconstruction of mandibular defects, the use of vascularized free tissue transfer is regarded as the gold-standard method in the developed

✉ Salwan Yousif Hanna Bede
salwan.bede@gmail.com; salwan.bede@codental.uobaghdad.edu.iq

Waleed Khaleel Ismael
dr.waleed.kh@gmail.com

Ehssan Ali Hashim
d.ehssanali@gmail.com

[1] Department of Oral and Maxillofacial Surgery, College of Dentistry, University of Baghdad, Bab-Almoadham, Baghdad, Iraq

[2] Oral and Maxillofacial Surgery Unit, Alyarmook Teaching Hospital, Baghdad, Iraq

countries [7]; it requires high skills and technologies which may be not available in developing countries [8]. The non-vascularized autogenous bone grafts, on the other hand, constitute another vital option for mandibular reconstruction [3]; they have been used regularly since the early 1960s [9]. The overall success of reconstruction depends on three main factors; the rigid fixation of the bone graft whether vascularized or non-vascularized, adequate soft tissue volume and vascularization, and the volume and contour of the reconstructed bone which should mimic the desired volume and contour of the missing part as close as possible [10].

Reconstruction plates are rigid plates, mostly made of titanium, that are applied along the lower border of the mandible; they are used for bridging defects, stabilizing remaining segments, and maintaining occlusion and facial contour and they are used to fix non-vascularized corticocancellous bone blocks or vascularized bone grafts to the remaining mandible [11].

Various complications associated with reconstruction plates have been reported in the literature, such as infection, wound dehiscence, plate exposure, loosening and breakage of screws, plate fracture, and other complications, and studies have also evaluated the effect of certain factors such as immediate or delayed reconstruction or the use of bone graft with the reconstruction plate on the occurrence of complications [11]; most of these studies, however, evaluated the complications associated with reconstruction plates in segmental defects created after ablative surgery with the use of various free or pedicled flaps; therefore, the purpose of this study was to evaluate the complications associated with the use of reconstruction plates with or without non-vascularized bone graft in reconstruction of mandibular segmental defects caused by trauma and tumor resection and to analyze various factors that are associated with the development of complications.

Materials and methods

This retrospective observational study included patients who underwent reconstruction of mandibular continuity defects caused by trauma or segmental resection of benign or malignant tumors using reconstruction plate with or without non-vascularized bone graft harvested from the anterior iliac crest during the period extending from 2010 to 2017. Patients who had mandibular reconstruction without using reconstruction plates were excluded from this study.

In patients with trauma-related defects, reconstruction was delayed after the preliminary management and stabilization of the patients' conditions and after thorough clinical and radiographic assessment of the extent of the defects. Immediate reconstruction was performed for the mandibular segmental defects created after resection.

Mandibular reconstruction with plates alone was performed in patients where tension-free closure of the intraoral tissues ensuring adequate isolation of the bone graft from the oral environment could not be achieved; this approach was to ensure a contamination-free tissue bed for future osseous reconstruction with bone graft. Reconstruction plates without bone graft were also used when the general health of the patient was compromised and a less extensive surgery was recommended or when the patient did not consent to have osseous reconstruction. Otherwise, reconstruction with plate and bone graft was performed.

Postoperatively, antibiotics and analgesics were routinely prescribed and patients were seen regularly at a weekly basis during the early postoperative period. The follow-up period was considered as the time between plate placement and the last examination visit, and during this time, all the complications were recorded and managed accordingly.

Throughout the study period, two reconstruction plate systems were used; according to the availability, the first system was 2.4-mm-thick titanium non-locking plates and 2.7-mm screws (W. Lorenz surgical, USA), and this system was used in 28 patients; the other system was 2.5-mm locking reconstruction plates and 2.4-mm and 2.7-mm screws (Matrix MANDIBLE, DePuy Synthes, USA), and this system was used in the remaining 23 patients.

The retrieved data of the patients included the age and gender of the patients, etiology of the defect whether trauma or tumor resection, the site of the defect (according to Jewer et al. 1989 [5]), the size of the defect measured at the inferior and/or posterior border of the mandible, whether bone graft was used or not, type of plate used (locking or non-locking), and whether the reconstruction was immediate or delayed. The outcome variables were the postoperative complications encountered during the follow-up period and the success rate; success was considered as a plate that does not have to be removed [12].

The complication rate was correlated with some investigated variables to demonstrate the factors that affected it. For this study, an institutional review board approval was not required due to its retrospective observational nature.

The statistical analysis was performed using GraphPad Prism version 6 for Windows (GraphPad Software, La Jolla, CA, USA). The descriptive analysis included percentages or mean ± standard deviation (SD). The investigated variables were analyzed statistically using the Student t test for two independent means and Fisher's exact test and the chi square test. The differences were considered significant at $P < 0.05$.

Results

Fifty-one patients with an age range of 9–67 years and a mean of 29.6 (± 11.5) years were enrolled in this study. The sample

consisted of 40 males (78.4%) and 11 females (21.6%) with a male:female ratio of 3.6:1. The etiology of mandibular defect was trauma in 39 patients (76.5%) and resection of benign or malignant tumors involving the mandible in 12 patients (23.5%). Of the trauma-related defects, the majority was caused by missile injuries in the form of bullets and explosions ($n = 34$, 87.2%) followed by road traffic accidents (RTA) ($n = 4$, 10.3%) and assault ($n = 1$, 2.5%). In the resection-related mandibular defects, the diagnosis was benign lesion in 9 patients (75%) and malignant lesions in 3 patients (25%). The follow-up period ranged from 6 to 40 months.

The size of the defect ranged from 10 to 120 mm with a mean of 49.4 (± 29.3) mm. Defects caused by trauma (40.4 ± 26.4 mm) were smaller than resection-related defects (72.7 ± 25.3 mm) and the difference was statistically significant ($P = 0.0099$).

Lateral (L) defects constituted the majority of defect types ($n = 37$, 72.5%) followed by central C defects ($n = 7$, 13.7%), and the distribution of the patients according to the defect site and the associated complication rate is summarized in Table 1.

Reconstruction was carried out using reconstruction plate alone in 36 patients (70.6%) and reconstruction plate and non-vascularized bone graft in 15 patients (29.4%).

Postoperative complications were identified in 30 patients (58.8%); these are summarized in Table 2. To note is that some patients developed more than one complication. Wound dehiscence with or without plate exposure was the most common complication ($n = 17$, 34.7%), the dehiscence was intraoral in 12 patients and extraoral in 5 patients; in all the patients, wound dehiscence occurred during the early postoperative period. Plate exposure was evident in 7 patients (14.3%) and it was mucosal (intraoral) in all cases which was managed successfully by refreshment and re-suturing in 6 patients.

Lateral (L) defects were associated with the lowest complication rate (51.4%), followed by C defects (57.1%) and H, HC, and LCL defects which showed 100% complication rates (Table 1).

The correlation between certain variables and the postoperative complication rate as shown in Table 3 revealed that the only factor that significantly increased the incidence of postoperative complications was the size of the defect.

Reconstruction plates had to be removed in 3 patients (5.9%) due to persistent complications rendering 94.1% success rate. These plates were removed due to wound dehiscence and plate exposure that did not respond to treatment in one patient, due to persistent infection which demonstrated loosening of screws in the second patient and due to plate fracture in the third patient.

Table 2 Postoperative complications

Complication	Number of occurrence (%)
Dehiscence	17 (34.7)
Limitation of mouth opening	8 (16.3)
Plate exposure	7 (14.3)
Infection	6 (12.2)
Malocclusion	6 (12.2)
TMJ pain	3 (6.1)
Plate fracture	1(2.1)
Loosening of the screws	1 (2.1)

Discussion

Reconstruction of the mandible has improved greatly resulting in a better functional and esthetic outcome; this improvement is related to surgical techniques and to hardware technology [6, 13]. The reconstruction plates are reported to provide rigid fixation of the bones and stable maintenance of occlusion and contour. However, several complications associated with these plates have been reported [14]. In this study, we retrospectively reviewed the data of patients who had mandibular segmental defects reconstructed with reconstruction plates with or without non-vascularized bone graft and analyzed some factors that may affect the incidence of postoperative complications.

The majority of patients in this study had mandibular segmental defects that were caused by trauma mostly through missile injuries ($n = 34$), and this type of injuries incur complex pattern of trauma characterized by bone and soft tissue loss and comminuted fractures of the facial bones [15], whereas in most studies, mandibular defects are mainly due to resection of benign or malignant lesions which may influence the comparison of this study with other reports.

The complication rate in this study (58.8%) is higher than that reported by other studies: 22.2% [16], 28% [17], 41.2%

Table 1 The distribution of patients and the complication rate in association with the site of the defect

Site of the defect	Total number of patients	Number of patients with complications/total (%)
L	37 (72.5)	19/37 (51.4)
C	7 (13.7)	4/7 (57.1)
H	3 (5.9)	3/3 (100)
LCL	3 (5.9)	3/3 (100)
HC	1 (1.9)	1/1 (100)

Table 3 The correlation between certain variables and the complication rate

Variables	Complications	No complications	*P* value
Age/mean (± SD)	30.15 (± 13.6)	28.45 (± 9.5)	0.7238 [NS]*
Gender			
Male	23 (57.5%)	17 (42.5%)	1.000 [NS]†
Female	7 (63.6%)	4 (36.4%)	
The size of the defect/mean (± SD)	64.2 (± 30.7) mm	32.7 (± 14.5) mm	0.003 [S]*
The etiology of the defect and timing of reconstruction/patients			
Trauma (delayed)	22 (56.4%)	17 (43.6%)	0.7391 [NS]†
Resection of pathology (immediate)	8 (66.7%)	4 (33.3%)	
Type of reconstruction/patients			
Reconstruction plate	22 (61.1%)	14 (38.9%)	0.7565 [NS]†
Reconstruction plate + bone graft	8 (53.3%)	7 (46.7%)	
Type of plate			
Locking	12 (52.2%)	11 (47.8%)	0.4078 [NS]†
Non-locking	18 (64.3%)	10 (35.7%)	

*Student's *t* test

† Fisher's exact test

[S] significant

[NS] non significant

[18], 43% [19], and 55.3% [20]. Wound dehiscence with or without plate exposure was the most common complication which involved intraoral wounds in most patients and resulted in plate loss (failure) in one patient. Of the 17 patients who had wound dehiscence, 7 had plate exposure and they were mucosal in all patients. This complication was observed in other studies in different rates: 8.8% [20], 17.1% [14], and 21.7% [19]. Kim and Donoff [14] and Yi et al. [20] demonstrated the significant effect of radiotherapy on the incidence of wound dehiscence and plate exposure and Ueyama et al. [18] reported plate exposure due to tumor recurrence. Knott et al. [13] reported that the time between plate implantation and extrusion was 4 to 36 months (median, 11.5 months) which is in contrast to this study where all the dehiscences occurred in the early postoperative period. Wound dehiscence and plate exposure, in this study, are mainly related to minor local infections and tension at the suture line in addition to the lack of bone support in continuity defects that may lead to mucosal wound dehiscence since all the patients had direct closure of the intraoral mucosal defects and none of our patients received pre- or postoperative radiotherapy.

Infection was encountered in 12.2 of the patients. Kim and Donoff [14] reported an infection rate of (26.8%) and they found no significant effect of the type of reconstruction whether plates or combined plates and bone graft and they also demonstrated no effect of immediate or delayed reconstruction on infection rate. Kirkpatrick et al. [21] reported that the use of reconstruction plates in treatment of complex and comminuted mandibular fractures demonstrated an infection rate ranging from 7 to 13% and they found that smoking increased the risk of postoperative infection and advocated the use of these plates in treatment of infected fractures.

In our series, the incidence of malocclusion and TMJ pain were 12.2% and 6.1% respectively; these complications may arise from the improper adaptation of the plates to fit passively to the buccal bone of the mandible which lead to distraction of the mandibular segments. These two complications were associated with large size defects and with patients with edentulous proximal segment of the mandible where there is no occlusal guidance to the proper alignment with the distal segment. The incidence of occlusal changes and TMJ pain were 9.8% and 14.6% respectively in other studies [14]. Ueyama et al. [18] reported TMJ pain in 2 patients of their sample that consisted of 34 patients (5.9%).

Loosening of screws was detected in 1 patient; it resulted in mobility of the plate and persistent infection which led to plate removal after 9 months of reconstruction without bone graft in a 65-mm lateral (L) defect. Studies have reported higher rates of loose screws ranging from 4.3 to more than 11% [16–18] and the suggested causes for this complication have been attributed to the forces generated by the muscles of mastication that lead to inappropriate forces on the bone around the screw threads leading to resorption of bone once the external forces exceed the limitations which the bone can withstand, in addition to ischemia caused by plate compression and the use of radiotherapy [18–20].

Using finite element analysis, some studies have made the observation that the maximum stress mostly occurred around the screw at the distal end of the mandibular half that is loaded and that the stress was significantly higher for defects

involving the central region than isolated lateral defects and that the concentration of stress was caused by vertical discrepancies between the screws and screw holes, they also revealed that the force of mastication has a leverage effect on the screw and lead to a higher tensile force on the screw closest to the defect than the force on the successive screws [19, 22].

Fracture of reconstruction plate occurred in one patient (2.1%) who had mandibular L-type 62-mm defect created after resection of a recurrent benign tumor that was reconstructed with reconstruction plate without bone graft as a setup surgery. A similar rate of plate fracture (2.9%) was reported by Ueyama et al. [18], whereas other studies reported higher rates [16, 17, 20, 23]. In their study, Shibahara et al. [23] identified lateral defects and reconstruction without bone graft and angular plates as risk factors for plate fracture. It is suggested that normal functional strain on the mandible leads to deformation of the mandibular arch and after implantation of devices such as plates, the biomechanics of bone change leading to postoperative complications [19].

In our series, plate fracture was diagnosed after about 2 years postoperatively, and the patient reported that malocclusion, pain, and swelling at the site of reconstruction were experienced after RTA; panoramic radiograph showed plate fracture. The palate was removed and the defect was reconstructed by another reconstruction plate and non-vascularized bone graft harvested from the anterior iliac crest (Fig. 1).

When correlating the complication rate with other independent variables in this study, age and gender were not significant factors that affected the complication rate; this is in line with other studies [16, 17]. The size of the defect, on the other hand, significantly increased the complication rate; this is in keeping with other studies that identified the defect size as a risk factor for development of complications and the success of reconstruction plates [17, 19], yet in contrast with other studies that did not show such correlation between plate survival and size of the defects [16].

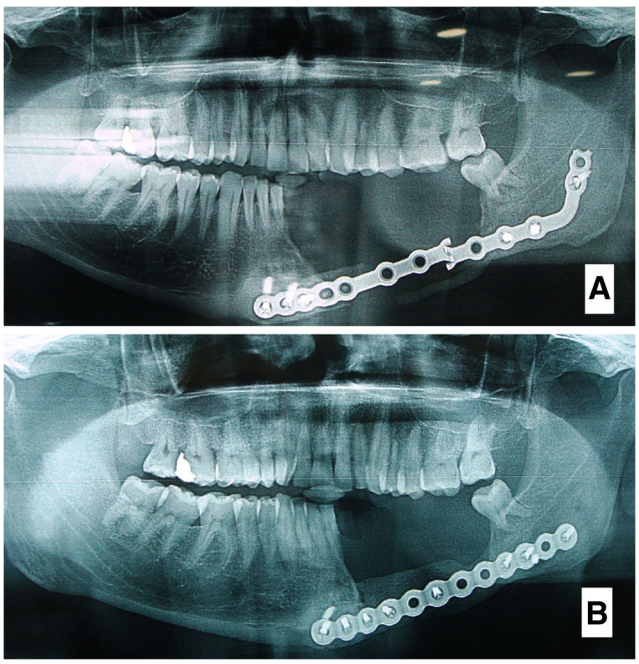

Fig. 1 **a** Panoramic radiograph showing fracture of reconstruction plate without bone graft. **b** Panoramic radiograph of the same patient after removal of the fractured plate and reconstruction of the mandibular defect with another reconstruction plate and bone graft

In the current study, lateral defects (L) showed the lowest rate of complications (51.4%), and this was followed by central defects (C) that resulted in (57.1%). The other types of defects showed 100% complication rate, but this latter rate should be considered with caution because only a small number of patients ($n = 7$) had H, HC, and LCL defects. The tendency for mandibular defects that cross the midline to result in higher complication rate is demonstrated in many studies that consider central defects to be a risk factor for complications [14, 19, 24] whereas Seol et al. [16] found that there was no significant difference in plate survival according to the location of the defect.

Trauma-related defects were caused by missile injuries in most of the patients ($n = 34$) making 87.2% of the trauma patients ($n = 39$) and 66.7% of the total patients. All patients with trauma-related defects received delayed reconstruction whereas the resection-related defects were reconstructed immediately. The decision to reconstruct with plates or plates and bone graft was made after clinical judgment of the adequacy of soft tissue covering, mainly intraorally, and the state of the graft bed which should be as less contaminated as possible especially in cases of missile injuries.

Although, patients with trauma-related defects showed less incidence of postoperative complications than patients with resection-related defects (56.4% and 66.7% respectively) which was possibly influenced by the fact that trauma caused significantly smaller sized defects than resection, but the difference did not reach statistical significance which can be attributed to the difference in the number of patients in these two groups (39 versus 12 patients). The same applies for the lower complication rate in patients who had combined plate and bone graft reconstruction, in addition to the possibility that these patients were judged clinically to be more suitable for bone graft than the other patients hence the lower complication rate. Kim and Donoff [14] in their study in 1992 also reported that the difference between the immediate and delayed reconstructions was not significant (19.2% and 26.7% respectively).

Non-locking plates resulted in higher complication rate than the locking plate, but the difference was statistically not significant. The locking plates are reported to have the advantage of enabling the screws to achieve rigid fixation without compression on the bone thus reducing complications [13], but some studies have reported comparable complication rates with different types of plates used in reconstruction of the mandible including locking and non-locking plates [25].

This study is limited in its small sample size and retrospective observational nature, but it differs from other studies in the literature in that it includes defects caused by trauma and resection in contrast to most studies that report mandibular defects created by resection of benign or malignant lesions that are reconstructed by reconstruction plates in addition to various pedicled or free vascularized flaps, and it also differs in that it does not include patients who had radiotherapy which excludes this controversial risk factor that was identified to increase complication rate and failure of reconstruction [14, 24], although some studies did not show such association [16, 17, 19]. The success rate (94.1%) in this study was higher than that reported in other studies which ranged from 71 to 85.2% [13, 16, 24]; this is probably due to the same aforementioned reasons. Kämmerer et al. [17] demonstrated that the plate survival rate progressively decreased over time from 73 to 40% within a 5-year period due to complications.

Considering its main limitations, this study concluded that reconstruction plates, despite their high complication rate, demonstrated a high success rate. It also showed that segmental defects caused by trauma were smaller than those created after tumor resection and that the only factor that increased complication rate was the size of the defect; other factors such as age, gender, etiology of the defect, timing of reconstruction, the use of bone graft, and the type of reconstruction plate did not statistically affect the complication rate.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Not required.

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