RESEARCH ARTICLE

A comparative of multiple rib fractures with embracing fixators and rib-locking titanium plates

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Abstract

Objective: To compare the clinical efficacy and safety between embracing fixator and rib-locking titanium plate in the treatment of multiple rib fractures.

Method: The retrospective study was conducted at the Sichuan Province Orthopaedics Hospital, China, and comprised clinical data from January 2020 to December 2022 of patients with multiple rib fractures. The patients were divided into the embracing fixator group A and rib-locking titanium plate group B. Data was analysed using SPSS 22.

Results: Of the 100 patients, 50(50%) were in each of the two groups. There were 35(70%) males and 15(30%) females in group A with mean age 51.38±10.62 years (range: 25-62 years) compared to 33(66%) males and 17(34%) females with mean age 51.48±10.93 years (range: 27-65 years) ($p>0.05$). Surgical duration and incisional length were shorter, and the blood loss was smaller in group B compared to group A ($p<0.05$). Three months after treatment, the visual analogue scale VAS) score of group B was lower than group A ($p<0.05$). All markers of pulmonary function significantly improved both groups ($p<0.05$) compared to baseline values, but group B patients showed more and better improvement than group A ($p<0.05$). There was no significant difference in terms of the incidence of complications between the groups ($p>0.05$).

Conclusion: The rib-locking titanium plate treatment for multiple rib fractures showed the advantages of minimal trauma, simple operation, minimal bleeding, low postoperative pain, significant improvement in lung function, and no increase in postoperative complications.

Keywords: Embracing fixator, Rib-locking titanium plate, Multiple rib fractures, Surgical method, Complications.

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Introduction

Thoracic traumas are currently common in clinics, with an incidence second only to head and limb traumas, of which rib fractures represent the most common injury.[1,2] According to statistics[3] about half of patients with thoracic traumas are complicated with rib fractures. Considering that rib fractures are often screened using thoracic X-ray in clinical practice, the incidence may be higher.[4] Mild rib fractures can only manifest as local pain, with no need for special treatment, and have a good prognosis. Severe rib fractures, especially multiple rib fractures, may lead to chest wall instability, which can cause atelectasis, pleural effusion, pulmonary infection and flail chest, affecting the respiratory function, and even resulting in acute respiratory distress syndrome (ARDS), thus endangering the lives of the patients.[5] The treatment of rib fractures is mainly divided into open reduction and internal fixation (ORIF), and conservative treatment and external fixation. It has been shown that for multiple rib fractures, surgical treatment can significantly reduce the incidence of respiratory failure and tracheotomy rate, significantly improve the prognosis of patients, and has a positive effect on the long-term prognosis.[6] With the development of internal fixation, there is a variety of internal fixators used in the treatment of multiple rib fractures, commonly including nickel-titanium shape memory alloy embracing fixator, pure titanium claw plate, rib-locking titanium plate, costal intramedullary plate, and absorbable intramedullary nail. Among them, the nickel-titanium shape memory alloy embracing fixator is the most widely used, but it needs secondary surgery for its removal after the fracture is healed. In addition, rib-locking titanium plate simulates the rib curvature, and it can fix the fractured ends without stripping the periosteum intraoperatively, needing secondary surgery to remove the internal fixator, or without causing secondary trauma to the patients.[7] However, it is a novel internal fixation material, which has been rarely applied in China.

The current study was planned to compare the clinical efficacy and safety between embracing fixator and rib-locking titanium plate in the treatment of multiple rib fractures.

Materials and Methods

The retrospective study was conducted at the Sichuan Province Orthopaedics Hospital, China, and according to the inclusion and exclusion criteria, clinical data of patients with multiple rib fractures were selected using a random

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number table method from January 2020 to December 2022.[8] After approval from the institutional ethics review committee, the sample size was calculated using out-of-bed activity time as an estimation indicator within a group design (differential design). The study kept a 1:1 ratio between the embracing fixator group and the locking titanium plate group, and the effective rate of the main efficacy indicator was calculated using the formula as: $N=2\times(Z_\alpha+Z_\beta)2\times\sigma^2/\delta^2$.[9] After literature research,[10] the effective rate of σ=0 83, δ=0.64, α=0.05 (bilateral), and β=0.10 (unilateral) were used, with Z α=1.96, and Z β=1.28. The calculated sample size was suitable inflated to cover for dropouts and to improve the power of the study. Written informed consent was obtained from all the participants, patients with multiple rib fractures (≥3), confirmed by X-ray or computed tomography (CT), meeting surgical indications, aged ≥18 years, those who were conscious, agreed to the surgical plan, and signed the surgical consent form were included. Patients with concomitant progressive haemothorax or other serious injuries, with concomitant coagulation dysfunction or severe systemic infection, with pathological fractures and incomplete clinical data were excluded.

The patients were divided into the embracing fixator group A and rib-locking titanium plate group B. Patients in group A underwent ORIF surgery under general anaesthesia (GA) with tracheal intubation. The appropriate body position, incisional site and length were selected according to the location of rib fractures. The tissues were cut open layer by layer, without cutting off the muscles, to completely expose the fractured ends. After removing the soft tissue at the fracture ends, the fractures were anatomically reduced. Then, an appropriate nickel-titanium shape memory alloy embracing fixator was selected and immersed in sterile saline at 0-5℃ for 5 minutes. Subsequently, it was placed on the rib surface after distraction, maintained with bone-holding forceps, and evenly compressed using gauze soaked in normal saline at 40-45℃ for 5 minutes. The fracture location was embraced by avoiding suspension on the rib surface to ensure the fixation effect. Later, the embracing fixator was tightened. After complete haemostasis, a thoracic drainage tube was indwelt routinely, and the incision was sutured layer by layer.

Patients in group B received anaesthesia, body position, incision and fracture reduction similar to group A. According to the rib curvature of the patients, the titanium plate was moulded with a moulder, placed on the rib surface, and was temporarily fixed using plate-holding forceps. The rib's surface was drilled with a bone drill and then locked with locking compression screws. After fracture fixation, fracture reduction and fixation were checked again. With satisfactory reduction and fixation, a thoracic drainage tube was indwelt routinely, and the incision was sutured layer by layer after complete haemostasis.

Perioperative data of the two groups was recorded. It included incisional length, intraoperative blood loss, surgical duration, out-of-bed activity time and hospital stay. The pain of patients was evaluated using the Visual Analogue Scale (VAS) score 3 days after the surgery. Complications in the two groups were observed 1 month after the surgery. Three months after the surgery, the healing of rib fractures was evaluated based on imaging results, and categorised as normal healing, abnormal healing (malunion) and nonunion. The therapeutic efficacy was evaluated 3 months after the surgery as excellent, good, medium and poor. Excellent meant normal breathing, no pain at the original fracture, bilateral thoracic symmetry, and excellent rib alignment in imaging examination. Good meant normal breathing, no pain at the original fracture, basic symmetry of bilateral thorax, and good rib alignment in imaging examination. Medium meant mild pain at the original fracture, mild collapse or asymmetry of the thorax, and poor alignment of a few ribs with the displacement within 3mm in imaging examination. Poor meant pain at the original fracture, and rib displacement >3mm. The pulmonary function indicators of the groups were measured before treatment and 3 months after the surgery. These included forced expiratory volume in the first second (FEV1), the percentage of FEV1 to the predicted value (FEV1%), forced vital capacity (FVC) and FEV1/FVC ratio.[4]

Data was analysed using SPSS 22. Data showed normal distribution, and was expressed as mean±standard deviation. Independent-samples t-test was used for intergroup comparison, and paired t-test was used for intragroup comparison between baseline and and post-intervention values. The counting data was expressed as frequencies and percentages, and intergroup comparisons were conducted with chi-square test. P<0.05 was considered statistically significant.

Results

Of the 100 patients, 50(50%) were in each of the two groups. There were 35(70%) males and 15(30%) females in group A with mean age 51.38±10.62 years (range: 25-62 years) compared to 33(66%) males and 17(34%) females with mean age 51.48±10.93 years (range: 27-65 years) (p>0.05). The number of fractures, causes of injury and complications were not significantly different between the groups (Table 1).

Out-of-bed activity time and hospital stay showed no

Table-1: General characteristics of the subjects.

Item	Embracing fixator group (n=50)	Titanium plate group (n=50)	t/χ2	*p*-value
Age (year)	51.38±10.62	51.48±10.93	0.046	0.963
Gender (male/female)	35/15	33/17	0.184	0.668
Number of fractures (n)	4.62±1.05	4.56±1.13	0.276	0.783
Cause of injury			0.820	0.936
Fall from height	21	23		
Traffic accident	12	12		
Crush by a heavy object	10	7		
Injury by violence	5	5		
Others	2	3		
Complication				
Haemopneumothorax	31	29	0.167	0.683
Pulmonary contusion	28	30	0.164	0.685
Sternal fracture	5	3	0.543	0.461

Table-2: Perioperative and pulmonary function indicators between the groups.

Observation indicator	Embracing fixator group	Titanium plate group	*t*-test	*p*-value
Surgical duration (min)	70.60±8.06	67.20±7.83	2.139	0.035
Incisional length (cm)	9.72±1.23	6.76±1.27	11.837	0.000
Blood loss (ml)	40.58±1.97	25.10±1.76	41.391	0.000
Out-of-bed activity time (d)	2.38±0.67	2.20±0.40	1.633	0.106
Hospital stay (d)	8.02±0.82	7.86±0.76	1.014	0.313
VAS score	1.82±0.72	1.46±0.84	2.304	0.023
FEV1 (L)				
Before treatment	1.35±0.31	1.31±0.28	0.597	0.552
After treatment*	1.92±0.41	2.08±0.35	2.026	0.046
FEV1%				
Before treatment	41.82±4.60	41.32±3.72	0.602	0.548
After treatment*	59.86±6.69	62.56±6.27	2.081	0.040
FVC (L)				
Before treatment	2.23±0.63	2.30±0.60	0.576	0.566
After treatment*	2.69±0.66	3.18±0.66	3.658	0.000
FEV1 /FVC				
Before treatment	0.65±0.24	0.61±0.22	0.877	0.383
After treatment*	0.74±0.18	0.88±0.28	3.153	0.002

Table-3: Comparison of clinical outcomes and complications between the groups.

Item	Embracing fixator group (n=50)	Titanium plate group (n=50)	χ2	*p*-value
Fracture healing			1.398	0.497
Healed	35(70.00)	39(78.00)		
Malunion	12(24.00)	10(20.00)		
Nonunion	6(6.00)	1(2.00)		
Therapeutic efficacy			0.735	0.865
Excellent	39 (78.00)	42(84.00)		
Good	6(12.00)	5(10.00)		
Medium	3(6.00)	2(4.00)		
Poor				
Complications			0.071	0.790
Pulmonary infection	3(6.00)	1(2.00)		
Atelectasis	2(4.00)	2(4.00)		
Chest pain	2(4.00)	3(6.00)		
Pleural effusion	2(4.00)	2(4.00)		

significant differences between the groups ($p>0.05$). Surgical duration and incisional length were shorter, and the blood loss was smaller in group B compared to group A ($p<0.05$). All markers of pulmonary function significantly improved in both the groups ($p<0.05$) compared to baseline values, but group B patients showed more and better improvement than group A ($p<0.05$) (Table 2).

Post-treatment VAS score of group B was lower than group A ($p<0.05$). There was no significant difference in fracture healing, therapeutic efficacy and post-intervention complications between the groups after surgery ($p>0.05$) (Table 3).

Discussion

Thoracic injuries rank third after head and limb injuries, of which rib fractures are more common. About half of the patients with thoracic injuries are accompanied by rib fractures.[11] Multiple rib fractures are defined as fractures of 3 or more ribs, with more complications than single rib fractures. For multiple rib fractures, the fractured ends can pierce into the thoracic cavity, damaging the pulmonary tissue, and causing pneumothorax, haemothorax or Haemopneumothorax, which can lead to abnormal respiratory movements and respiratory failure, and seriously affect the patients' respiratory function. Most patients with rib fractures have poor prognosis, and some present abdominal visceral injuries caused by the fractured ends piercing into the thoracic cavity.[12,13] Therefore, active clinical intervention is needed for multiple rib fractures to reduce the symptoms, and improve the prognosis of the patients. The treatment of multiple rib fractures mainly comprises fixation, supplemented by ventilation, analgesia, drainage and anti-infection measures. There are two main fixation methods: external fixation and ORIF.[14] In the past, due to the high cost of internal fixation, external fixation was mainly used.[15] However, thoracic wall stability is poor in multiple rib fractures, and external fixation is difficult to achieve reduction and fixation. With the development of internal fixation technology and materials, ORIF is increasingly widely recognised. It has been demonstrated that ORIF not only can improve the short-term prognosis of the patients, but also has a positive effect on the long-term prognosis.[16] The current study showed that the application of internal fixation in the treatment of multiple rib fractures could significantly improve postoperative pulmonary function of the patients ($p<0.05$).

At present, nickel-titanium shape memory alloy embracing fixator has been the most widely used in the treatment of rib fractures. It is physically characterised by moulding at low temperatures, memory shape restoration at room temperature, and good clamping capability, so that it can well maintain the stability of the fractured ends, with simple operation and short surgical duration.[17,18] Nevertheless, the application of this internal fixation material has some disadvantages, such as intraoperative damage to the periosteum, costal nerves and vessels, as well as postoperative pain and numbness in the surgical area.[19] Pre-contoured rib-locking titanium plate is a novel internal fixation material for the treatment of rib fractures.[20] Currently, compared to nickel-titanium shape memory alloy embracing fixator in clinical application, this internal fixation material has no need for stripping the periosteum during surgery.[21] Combined with locking screws, it can firmly fix the fractured ends, with less surgical trauma and simple operation. In addition, because of no nerves or blood vessels involved in intraoperative stripping, the intraoperative blood loss is small, the postoperative pain is less, and the postoperative complications are few.[22,23] In the current study, the results revealed that compared to the embracing fixator group, the titanium plate group had shorter surgical duration, shorter incisional length, less blood loss and milder postoperative pain ($p< 0.05$), and no significant difference was noted in terms of postoperative complications ($p>0.05$).

Multiple rib fractures often cause severe chest pain and poor thoracic stability, resulting in limited respiratory movements, which seriously affect the pulmonary function.[24,25] Additionally, patients with fracture-related pain dare not cough or breathe deeply, so it is likely to cause sputum retention, leading to fracture-related complications, such as atelectasis or pulmonary infection.[26,27] After internal fixation for fractures, paradoxical respiration can be eliminated, thus effectively relieving pain, accelerating pulmonary recruitment, improving pulmonary function, and reducing pulmonary complications in the patients. According to the current results, the pulmonary function indicators of both the groups significantly improved after the surgery ($p<0.05$), which was more obvious in the titanium plate group than in the embracing fixator group ($p<0.05$).

The current study has limitations of being a single-centre study with a small sample size. There may be a sample selection bias, which has an impact on the findings. There is a need to conduct randomised controlled trials (RCTs) with a strict design to further explore the advantages of rib-locking titanium plates in the treatment of multiple rib fractures.

Conclusion

In patients with multiple rib fractures, rib-locking titanium plate could achieve the same clinical efficacy as nickel-titanium shape memory alloy embracing fixator, and significantly improved the pulmonary function of patients. Moreover, it had the advantages of less trauma, simple operation, small blood loss and less pain, with no increased postoperative complications, and no postoperative need for secondary removal. The clinical safety was high as well.

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Author Contribution:

WW: Design, final approval and agreement to be accountable for all aspects of the work.

YQ: Collected and analysed clinical data, final approval and agreement to be accountable for all aspects of the work.