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ORIGINAL ARTICLE

Usefulness of sternal closure with bioresorbable plate in respiratory function after coronary artery bypass grafting

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Abstract

Objective The aim of our study is to investigate that sternal reconstruction using bioresorbable plate in median sternotomy may reduce postoperative respiratory dysfunction when compared with wire cerclage only.

Methods We reviewed 107 patients who were undergone coronary artery bypass grafting with median sternotomy. Patients were divided into two groups; patients underwent sternal reconstruction with bioresorbable plate and wire cerclage (S group, $n=56$), patients with wire cerclage only (N group, $n=51$), and perioperative respiratory function and postoperative pain score data were analyzed and compared between two groups.

Results There was no significantly difference in preoperative respiratory function in both groups. However, in postoperative change rate of respiratory function, N group had significant decrease compared with S group in vital capacity (VC) (N: S = 74.8 ± 12.4: 85.2 ± 14.8%, $p=0.020$), VC as a percentage of predicated VC (N: S = 75.0 ± 12.5: 86.4 ± 15.1%, $p=0.012$), and forced expiratory volume in the first second (N: S = 73.7 ± 9.2: 85.3 ± 16.4%, $p=0.012$). In Prince Henry Pain Scale, there were significantly more in N group compared with S group (N: S = 3.4 ± 1.0: 2.6 ± 1.4, $p=0.003$).

Conclusion Sternal fixation with bioresorbable plate could reduce impairment of postoperative respiratory function in comparison to wire cerclage only.

Keywords Respiratory function · Coronary artery bypass grafting · Median sternotomy · Bioresorbable plate

Introduction

A decrease in pulmonary function is a frequency observed complication after cardiac surgery. Several studies reported that vital capacity (VC) after coronary artery bypass grafting (CABG) decreased by 30–60% [1–4].

Wire cerclage is the standard technique of median sternotomy closure for most cardiac surgeons in median sternotomy. Although this method is simple and easy, past studies have showed that rigid fixation of the sternum with plates and screws resulted in mechanical properties superior to wire closure [5–7].

Super FIXSORB® MX40 mesh plate (Teijin Medical Technologies CO. Ltd., Osaka, Japan) (SFMX) is a kind of bone plate. It is bioresorbable, and is composed of both unsintered and uncalcined hydroxyapatite and poly-L-lactic acid. This mesh plate is resorbed in body in about 6 years while including osteoconduction [8]. SFMX has already been used for fixing rib fracture [9, 10] or repair of flail chest [11]. Even more, Tanaka et al. [12] reported that postoperative respiratory and hemodynamic condition were more stable with SFMX in fixing median sternotomy after congenital cardiac surgery.

The purpose of this study was to investigate the availability of SFMX for rigid sternal fixation and evaluate SFMX for postoperative effect of respiratory function after CABG.

Subjects and methods

This retrospective study was approved by the institutional review board, and a waiver of informed consent was obtained.

A total of 111 consecutive patients were undergone elective CABG alone from February 2013 to July 2018 in our institution. We investigated the patients excluded patients without median sternotomy, with bilateral internal

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thoracic arteries, and with SternaLock Plates (Biomet Microfixation CO. Ltd., Jacksonville, FL). So, 107 patients undergone elective CABG alone with median sternotomy were intended. In this study, all patients were undergone CABG with single internal thoracic artery. Mean age was 69.8 ± 9.0 years (41–84 years), and fourteen patients were women (13.1%).

Basic sternal fixation is conventional wire cerclage. We have administered SFMX for the all target patients since December 2015 (S group, $n = 57$). As a reference, the consecutive target patients undergone CABG before the due day (from February 2013 to November 2015) were N group ($n = 51$). Two groups were compared to the following clinical variables. All data are collected at the point of care and serve to create both medical reports and a scientific data base, and the quality of the primary data is reliable.

All patients were performed to sternal closure with conventional wire cerclage. It was performed using simple and single wires, and the number of wires was six. Two transsternal wires were at the manubrium and four pare-sternal wires were at the sternal body.

The four corners of SFMX were cut with scissors. SFMX was fixed by passing two cranial para-sternal wires (third, fourth) through holes of SFMX, and then each of the wires were tied (Fig. 1a, b). The chest was closed using the conventional technique.

With cardiac rehabilitation stuffs, we always investigated perioperative respiratory function of patients underwent cardiac surgery. They were studied based on spirometry examinations which was performed on preoperative day (baseline value) and the fourteenth postoperative day (follow-up values). Analyzed spirometry parameters were VC, VC as a percentage of predicated VC (%VC), forced expiratory volume in first second (FEV1.0) and FEV1.0 as a percentage of forced vital capacity (FEV1.0%). The postoperative change rates of respiratory function were presented as a percentage of preoperative values.

Postoperative pain was evaluated by Prince Henry Pain Scale (PHPS) [13]. Acetaminophen (1200 mg/day) is taken for analgesic drug in all patients. Patients with PHPS > Score 4 were prescribed on pentazocine.

Diabetes mellitus (DM) was defined as the recent use of anti-diabetic drugs, fasting blood glucose > 126 mg/dl and/or hemoglobin $A_{1c} > 6.5\%$. Chronic kidney disease (CKD) was defined as estimated glomerular filtration rate (eGFR) < 50 ml/min/1.73 m^2.

Continuous data are expressed as mean ± SD with ranges when appropriate. Non-parametric Mann–Whitney *U* test

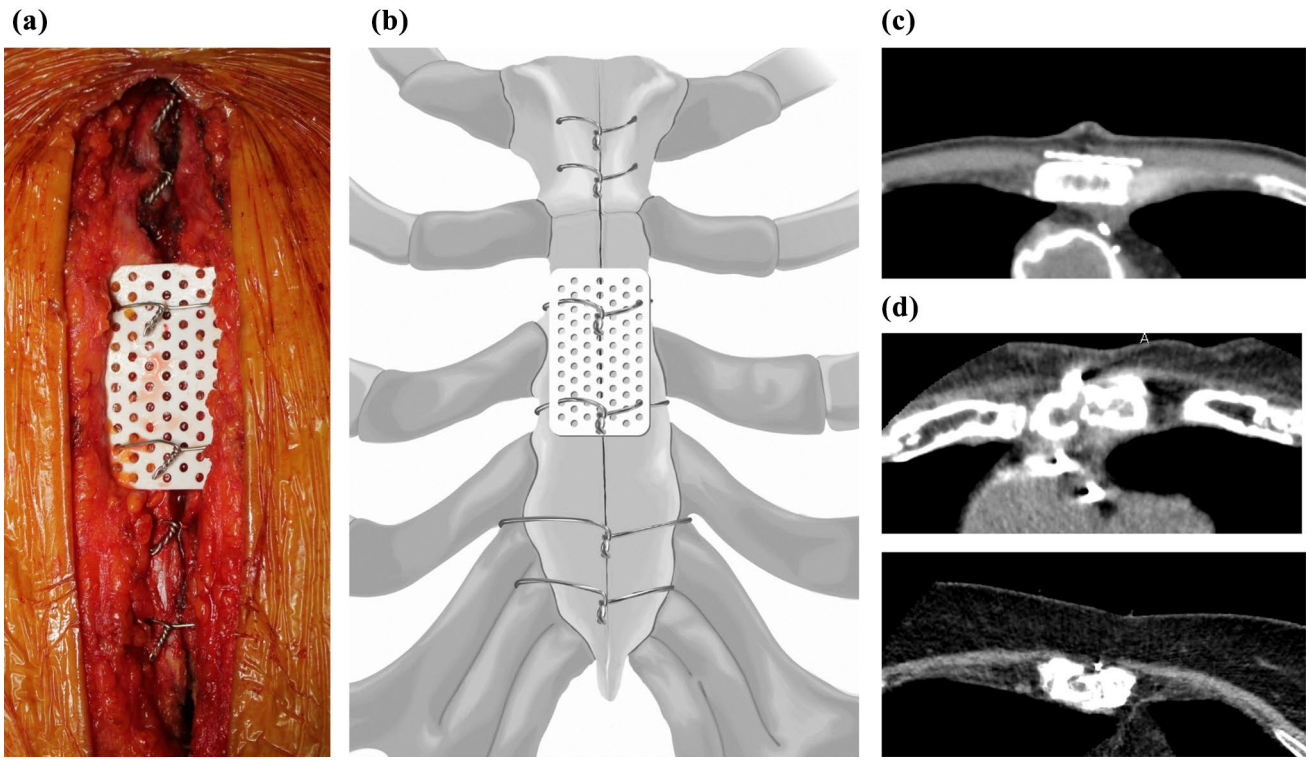


Fig. 1 Sternum was fixed by Super FIXSORB® MX40 mesh plate (SFMX). SFMX was fixed by passing two cranial para-sternal wires; **a** external appearance of the sternum at the end of the operation. **b** Diagram of sternum fixation technique using SFMX. **c** Postoperative computed tomographic scanning. There was no gap between median sternotomy in fixation with SFMX. **d** Postoperative computed tomographic scanning. There were gaps between median sternotomy in fixation without SFMX

was used. Parametric data were examined with contingency tables, with Fisher's exact test, as appropriate. The associated variables were included in the stepwise backward selection method in the multivariable model to identify the independent predictors of prevention for postoperative respiratory function depression, presented as odds ratio (OR) with 95% confidence intervals (CI). Differences were considered significant at $p < 0.05$.

Results

There were data before interventions for all patients in Table 1. There was no significant difference among groups in age, sex, hypertension, dyslipidemia, chronic obstructive pulmonary disease, smoking within a month, chronic kidney disease (excluded patients with hemodialysis), and hemoglobin value.

Table 1 Demographic characteristics of all patients

	N group ($n=51$)	S group ($n=56$)	p value
Preoperative			
Age (year)	69.7 ± 8.1	70.0 ± 9.8	0.883
Sex (male)	42 (82.4%)	44 (78.6%)	0.627
Body mass index (kg/m^2)	23.4 ± 3.7	24.2 ± 3.7	0.271
Prevalence			
Obesity	13 (25.5%)	17 (30.4%)	0.541
Hypertention	44 (86.3%)	53 (94.6%)	0.140
Dyslipidemia	43 (84.3%)	45 (80.4%)	0.597
DM	27 (52.9%)	35 (62.5%)	0.322
COPD	7 (13.7%)	16 (28.6%)	0.063
Smoking within a month	10 (19.6%)	12 (21.4%)	0.818
CKD	4 (7.8%)	12 (21.4%)	0.050
History of stroke	3 (5.9%)	5 (8.9%)	0.554
Peripheral arterial disease	6 (11.8%)	5 (8.9%)	0.633
Hb (g/dl)	13.2 ± 2.0	13.0 ± 1.8	0.588
Ejection fraction (%)	58.4 ± 12.6	58.4 ± 11.7	0.985
Surgical intervention			
OPCAB	17 (33.3%)	28 (50.0%)	0.220
Number of anastomosis	3.4 ± 1.1	3.4 ± 0.9	0.849
Operative time (min)	427.0 ± 100.8	401.8 ± 124.0	0.255
Circulation time (min)	203.1 ± 82.3	213.2 ± 119.4	0.672
Minimum rectum temperature (°C)	35.2 ± 0.9	34.8 ± 1.2	0.081
Use of IABP	3 (5.9%)	3 (5.4%)	0.907
Blood transfusion	35 (68.6%)	43 (76.8%)	0.348
Postoperative complications			
Intubation time (h)	22.0 ± 21.2	18.4 ± 10.8	0.270
ICU stay (day)	6.1 ± 1.6	5.2 ± 1.4	0.003
Hospital stay (day)	22.6 ± 7.7	22.7 ± 8.0	0.943
Re-stenotomy	2 (3.9%)	2 (3.6%)	0.909
Mediastinitis	2 (3.9%)	2 (3.6%)	0.909
Atrial fibrillation	16 (31.4%)	12 (21.4%)	0.222
Re-intubation	2 (3.9%)	2 (3.6%)	0.909
Hospital death	0 (0%)	0 (0%)	
Prince Henry Pain Scale			
Score	3.4 ± 1.0	2.6 ± 1.4	0.003
Score 4	34 (66.7%)	22 (39.3%)	0.004

DM diabetes mellitus, *COPD* chronic obstructive pulmonary disease, *CKD* chronic kidney disease, *Hb* hemoglobin, *OPCAB* off-pump coronary artery bypass grafting, *IABP* intra-aortic balloon pumping

In operative factors (rate of off-pump CABG, operation time, circulation time, et al.), there was no difference between both groups (Table 1).

Postoperative computed tomography scanning showed that there was no gap between median sternotomy in fixation with SFMX (Fig. 1c), by contrast, there were the gaps of sternotomy in N group (Fig. 1d). In Table 1, there was no difference between both groups on other postoperative complications (re-stenotomy, mediastinitis, atrial fibrillation, re-intubation, and hospital death). However, on postoperative pain, there were significantly lower patients with PHPS in S group than in N group (Table 1).

Perioperative respiratory functions were presented in Table 2. Preoperative respiratory functions were similar between both groups. However, postoperative change rates of respiratory function were shown in Fig. 2a–d. N group had significant decrease compared with S group in VC (N: S = 74.8 ± 12.4: 85.2 ± 14.8%, $p = 0.020$), %VC (N: S = 75.0 ± 12.5: 86.4 ± 15.1%, $p = 0.012$), and FEV1.0 (N: S = 73.7 ± 9.2: 85.3 ± 16.4%, $p = 0.012$). There was no significant change in FEV1.0%.

Discussion

The present study showed that postoperative respiratory function based on spirometry examinations was less impaired by sternal reconstruction with bioresorbable plate in median sternotomy.

The past study reported that external fixation of a bone fracture relieved pain and improved quality of life [14]. A bioresorbalble plate consinsting of poly-L-lactic and unsintered and uncalcined hydroxyapatite, as SFMX, has superior osteoconductive properties, bonds bone fracture, and promotes good bone healing without pseudoarticulation [9]. Though there were many reports for fixing rib fracture with bioresorbable plate [9–11], the study for fixing median sternotomy with bioresorbable plate in cardiac surgery was few.

Table 2 perioperative respiratory function

	N group ($n = 51$)	S group ($n = 56$)	p value
Pre-VC	2.98 ± 0.74	2.97 ± 1.00	0.964
Post-VC	2.23 ± 0.33	2.54 ± 0.70	0.100
Pre-%VC	92.0 ± 14.5	89.3 ± 18.0	0.418
Post-%VC	71.4 ± 11.1	75.9 ± 13.5	0.256
Pre-FEV1.0	2.25 ± 0.60	2.27 ± 0.80	0.895
Post-FEV1.0	1.67 ± 0.35	1.92 ± 0.62	0.138
Pre-FEV1.0%	76.9 ± 8.1	77.3 ± 8.2	0.733
Post-FEV1.0%	76.1 ± 11.6	76.8 ± 9.3	0.824

VC vital capacity, *%VC* a percentage of predicated VC, *FEV1.0* forced expiratory volume in first second, *FEV1.0%* a percentage of forced vital capacity

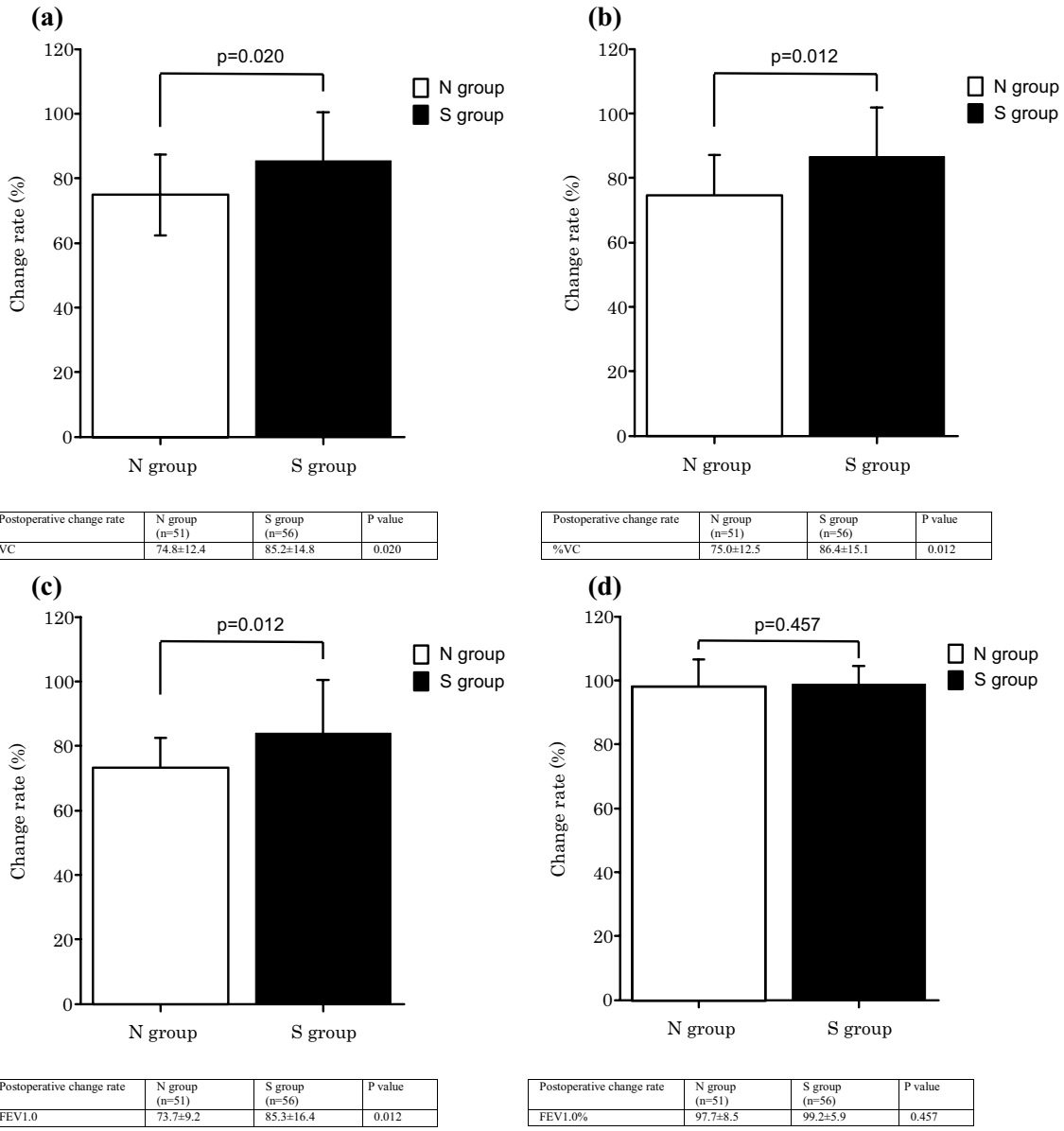
Tanaka et al. [12] reported that postoperative respiratory and hemodynamic condition were more stable with SFMX in fixing median sternotomy after congenital cardiac surgery. Sakashita et al. [15] confirmed fixation sternotomy with SFMX promoted bone stability and decreased post-surgical pain. We showed that fixation with SFMX got stability of sternum closer (Fig. 1c) and decreased postoperative pain (Table 1).

Additionally, Sakashita et al. [15] used two pieces of half SFMX for longitudinal sternotomy line. However, we thought line fixation could not prevent back and forth gap of sternotomy adequately, and we fixed one plate for enhancing bone face fixation. So, SFMXs were fixed intercostally. In our study, SFMX improved the gap of sternotomy (Fig. 1c), and the possibility was suggested that the advantages of SFMX, such as good stability of sternotomy, might beneficially affect reducing impairment of postoperative respiratory functions (Fig. 2a–c).

After cardiac surgery, there are many kinds of complications, such as diminished respiratory function and chronic surgical pain, from patients are prone to suffer from [16–19]. Especially in the pulmonary function, there were a few reports to treat the latter conditions. Roncada reported that osteopathic treatments might be effective treatment for decreased pulmonary function, chronic thoracic pain and diminished thoracic mobility after CABG surgery [20]. And then, inspiratory muscle training insertion in the preoperative period to cardiac surgery indicated an improvement in forced vital capacity and maximum voluntary ventilation [21]. However, these methods were physical rehabilitation program therapies. To our knowledge, there are no effective preventive interventions. Our study presented that sternum closer with SFMX decreased impairing postoperative respiratory function (Fig. 2). Because the sternal fixation with SFMX achieved sternum stability and diminished thoracic pains, reduction of pulmonary function after CABG might be decreased.

SFMX is a bioresorbable mesh plate composed of unsintered and uncalcined hydroxyapatite and poly-L-lactic acid. Though this sheet is resorbed in body in about 6 years while including osteoconduction [8], it could lead to complication like infection. We have found no report to suggest that SFMX increased inflammation-infections. In the present study, the instance of mediastinitis was similar between both groups (Table 1). Though there were potential risks like infection, swelling and pain, SFMX was considered a safe device with no adverse reaction [9].

The other device for rigid sternal fixation is SternaLock Plates (Biomet Microfixation, Jacksonville, FL). This rigid plate fixation is performed using one plate at the manubrium and two plates on the sternal body. Though



Postoperative change rate	N group (n=51)	S group (n=56)	P value
VC	74.8±12.4	85.2±14.8	0.020

Postoperative change rate	N group (n=51)	S group (n=56)	P value
%VC	75.0±12.5	86.4±15.1	0.012

Postoperative change rate	N group (n=51)	S group (n=56)	P value
FEV1.0	73.7±9.2	85.3±16.4	0.012

Postoperative change rate	N group (n=51)	S group (n=56)	P value
FEV1.0%	97.7±8.5	99.2±5.9	0.457

Fig. 2 Postoperative change rate of respiratory function; **a** vital capacity (VC). **b** Vital capacity as a percentage of predicated vital capacity (%VC). **c** Forced expiratory volume in first second (FEV1.0). **d** Forced expiratory volume for 1 s expressed as a percentage of forced vital capacity (FEV1.0%)

sternal reconstruction using SternaLock Plates improved bone healing and reduced early postoperative pain [22], the study about postoperative respiratory function have not been reported. SternaLock Plates are not resorbed in body and are represented on X-ray. Additionally, the method using SternaLock Plates is more complicated compared with SFMX, and needed with special tool when re-sternotomy.

The results of this study should be interpreted in the light of certain limitations. Firstly, ours is a retrospective study. Secondly, the present study was a single-center experience, and as a result it was limited by the relatively small number of patients included. Therefore, further prospective studies with a large group are needed.

Conclusion

Sternal fixation with bioresorbable plate is a simple, easy, and safe technique, and this method could reduce impairment of postoperative respiratory function in comparison to wire cerclage only.

Compliance with ethical standards

Conflict of interest There is no conflict of interest for this article.

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