



Original Research

One stage posterior debridement, non-structural bone graft in the surgical treatment of single segment thoracic tuberculosis: A retrospective single-center cohort study



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ABSTRACT

Objective: To compare the clinical efficacy of non-structural with structural bone graft in the surgical treatment of single segment thoracic tuberculosis after one stage posterior debridement.

Methods: 61 patients with single segment thoracic tuberculosis treated by one stage posterior debridement, bone graft fusion and internal fixation were retrospectively analyzed. Among them, 35 cases were admitted from 2015 to 2017 in the non-structural bone graft group and 26 cases were admitted from 2011 to 2015 in the structural bone graft group. The visual analogue scale (VAS), erythrocyte sedimentation rate (ESR), C reactive protein (CRP), neurological function, operation time, operative blood loss, hospital stay, correction and loss of Cobb angle, bone graft fusion time and complications were recorded and analyzed.

Results: Compared with structural bone graft group, the operation time of non-structural bone graft group was shorter and the operative blood loss was less, but the hospital stay was longer ($P < 0.05$). With the follow-up of 14–44 months, the VAS score, ESR, CRP and neurological function in the two groups were both improved ($P < 0.05$). The correction and loss of Cobb angle in the non-structural bone graft group were both smaller than those in the structural bone graft group ($P < 0.05$). The bone graft fusion time of the non-structural bone graft group was significantly shorter than the structural bone graft group ($P < 0.05$). No significant difference was found in the incidence of complications between the two groups (n.s.).

Conclusion: Non-structural bone graft has less surgical trauma and shorter bone fusion time compared with structural bone graft in the surgical treatment of single segment thoracic tuberculosis. The two methods may achieve comparable clinical efficacy in alleviating symptoms, correcting kyphosis and improving neurological function for appropriate cases.

1. Introduction

Spinal tuberculosis is the most common bone tuberculosis, which can cause vertebral collapse, kyphosis and even paralysis [1,2]. Chemotherapy has been recognized as the cornerstone of the treatment of spinal tuberculosis [3]. Surgical treatment is required for decompress spinal cord and nerve, correct kyphosis, and reconstruct spinal stability [4,5]. At present, chemotherapy combined with surgery when necessary is considered the main treatment for spinal tuberculosis [6].

The goal of spinal tuberculosis surgery is to radically debride lesions, relieve spinal cord compression and reconstruct spinal stability. Radical debridement is the key to spinal tuberculosis surgery [7], and bone grafting is necessary to restore the height of the vertebral body and reconstruct the stability of the spine [8]. It is reported that structural bone graft is the most common method in spinal tuberculosis

surgery, such as iliac bone graft, titanium mesh bone graft, allograft bone graft and so on [9–11]. With the improvement of the diagnosis and treatment of spinal tuberculosis and the development of posterior internal fixation technology, it is reported that non-structural bone graft can also achieve satisfactory clinical efficacy in the treatment of some spinal tuberculosis. Liu et al. [12] reported 21 cases of lumbosacral tuberculosis treated with one stage posterior debridement, non-structural bone graft and internal fixation, and all patients have bone graft fusion within 6 months. Xu et al. [13] included 32 cases of single segmental lumbar tuberculosis with single-stage posterior debridement, compact bone graft and internal fixation, and all patients encountered bone fusion within 3–9 months. Liu et al. [14] compared the clinical efficacy of one-stage posterior debridement with non-structural autogenous bone graft (39 cases) versus anterior debridement, structural bone graft combined with posterior instrumentation (34 cases), and the

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results revealed the former method has a significantly shorter operation time, lower blood loss, shorter hospital stay and less hospitalization cost, but no difference in the bone graft fusion time was found. However, this conclusion may be biased because the surgical approaches used in the two groups were quite different. The difference in clinical efficacy between non-structural and structural bone graft methods remains unclear.

Therefore, we conducted this retrospective single-center cohort study to compare the clinical efficacy of structural and non-structural bone graft in the treatment of single segment thoracic tuberculosis. Our previous study found that there was no significant difference in clinical symptoms, correcting kyphosis and bone graft fusion time between iliac bone graft and titanium mesh bone graft [15], so we classified both of them as structural bone graft group in this study.

2. Materials and methods

All of the participants provided their written informed consent to participate in this study before their data were stored in the hospital database and used for research purposes. The work has been reported in line with the STROCSS criteria [16].

2.1. Patients selection

Spinal tuberculosis patients treated with structural bone graft from 2011 to 2015 and non-structural bone graft from 2015 to 2017 were retrospectively analyzed.

Inclusion criteria: (1) Preoperative diagnosis of thoracic spinal tuberculosis is confirmed by postoperative pathological examination. (2) Thoracic spinal tuberculosis involved single segment. (3) Surgical method was one-stage posterior debridement, bone graft fusion and internal fixation. (4) The methods of bone grafts were structural bone graft (iliac bone graft, titanium mesh bone graft) or non-structural bone graft (autologous granular bone graft). (5) The follow-up time was more than 12 months. (6) The clinical and imaging data during the follow-up were complete.

Exclusion criteria: (1) Suspected spinal tuberculosis patients without pathological examination. (2) Multi-segmental spinal tuberculosis, cervical or lumbar spine tuberculosis. (3) Patients with previous history of spinal surgery. (4) Spinal tuberculosis with active pulmonary tuberculosis or malignant tumor.

2.2. Preoperative management

X-ray, CT and MRI were performed in all patients before operation in order to find out the degree of vertebral damage, intervertebral space, cold abscess and the compression of spinal canal. All patients were treated with regular anti-tuberculosis drugs (rifampicin 450 mg/d, isoniazid 300 mg/d, pyrazinamide 1500 mg/d, ethambutol 750 mg/d) for 2–4 weeks before surgery. Surgery was conducted after the symptoms of tuberculosis poisoning were alleviated, the erythrocyte sedimentation rate (ESR) decreased below 50 mm/h and the patients' basic diseases such as diabetes, coronary heart disease and hypertension were controlled and stabilized.

2.3. Surgical methods

The choice of bone graft method was mainly based on the following principles: (a) Structural bone graft was mainly used for patients with bony destruction exceeding 50% of the vertebrae height. Iliac bone graft was used for young patients with less basic diseases and good operative tolerance, while titanium mesh bone graft was used for middle-aged or elderly patients with more basic diseases and poor operative tolerance. (b) Non-structural bone graft was mainly used for patients with bony destruction less than 50% of the vertebrae height.

The patients were placed in the prone position after general

anesthesia, and C arm X ray was used to confirm the lesion segment. Subperiosteal detachment of the bilateral paravertebral muscles was performed via the posterior median approach (if the lesion was unilateral, the intermuscular approach was applied to the contralateral side). Expose the spinous process, lamina, articular process and the transverse process of the lesion segment, the upper and lower adjacent normal vertebrae. Then pedicle screws were inserted into the one or two normal vertebrae above and below the lesion segment, pedicle screws were inserted in lesion segments as possible (when vertebrae were severely destroyed, pedicle screws were just placed on the contralateral side) and the titanium rod was locked temporarily. Resect bilateral vertebral plate of lesion segments, protect the dural sac and nerve root, and the decompress the spinal canal. Pedicle of the lesion segment could also be removed when necessary. Different types of curette were used to strike off caseous necrosis, intervertebral disc, dead bone, bone sclerosis and keep the relative healthy bone tissue till bone surface bleeding. The posterior screw system was properly pressurized to correct kyphosis and C-arm X-ray was used to confirm the degree of the kyphosis correction.

The bone graft bed was designed and bone graft was performed with different methods: (1) Structural bone graft group: Harvest an iliac bone with three sides of cortex, prune the size suitable and implant it into the vertebral body, or mix the crushed bone block with 1.0 g streptomycin and fill it into a suitable titanium mesh and then implant it into the vertebral body (Fig. 1). (2) Non-structural bone graft group: The vertebral plate and spinous process harvested during surgery were made into 3–5 mm granular bone and then implanted into the vertebral body and tamped them down. The posterior margin was covered with a gelatin sponge containing isoniazid to prevent granular bone from entering the spinal canal (Fig. 2). In all cases, streptomycin 1.0 g and isoniazid 0.3 g were placed in the lesion area, two drainage tubes were placed in the incision and then the incision was closed layer by

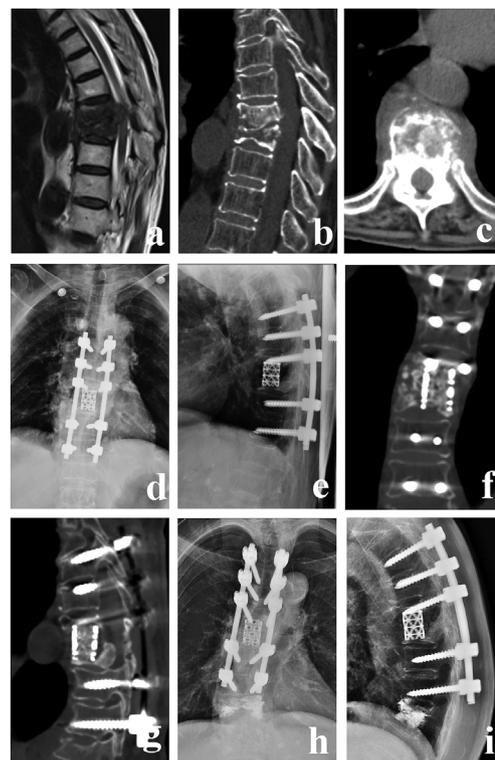


Fig. 1. Structural bone graft group. A 76-year-old female with T8-9 tuberculosis. (a–c) Preoperative MRI and CT showed that T8-9 vertebral bone destruction with intervertebral space stenosis. (d, e) Postoperative X-ray showed titanium mesh cage and screw rod were in good location. (f–i) CT and X-ray at 8 months postoperative showed bone fusion between T8 and T9.

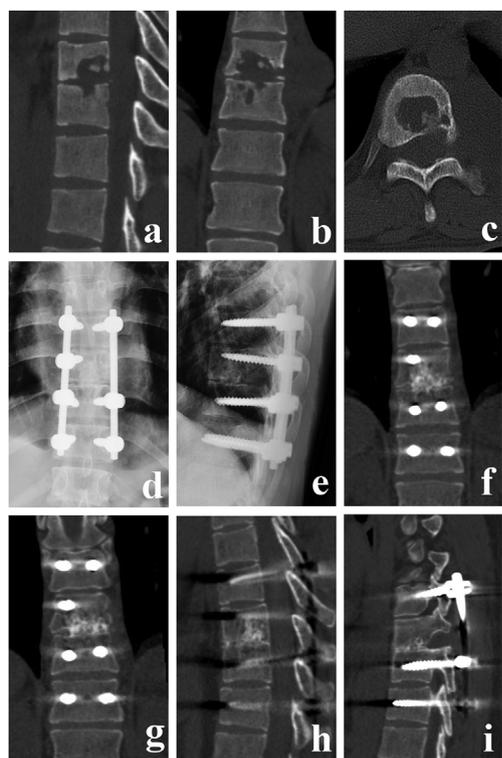


Fig. 2. Non-structural bone graft group. A 24-year-old male with T9-10 tuberculous. (a–c) Preoperative CT showed that T9-10 vertebral body destruction with dead bone formation and intervertebral space stenosis. (d, e) Postoperative X-ray showed granular bone graft and internal fixation was in good location. (f–i) CT at 5 months postoperative showed bone fusion between T9 and T10.

layer.

2.4. Postoperative management

Prophylactic use of antibiotics for 3 days was needed after surgery. The drainage can be removed when the drainage volume was lower than 40 ml/d and then X-ray film was rechecked. Continue preoperative anti-tuberculosis drug therapy for 18–24 months after operation. One week after the operation, patients can wear a brace to stand up and brace was applied for postoperative 3–6 months. X-ray, ERS, CRP, liver and kidney function and CT and MRI (if necessary) were examined in 1, 3, 6, 12 months after operation.

2.5. Outcome indexes

Clinical outcomes: (1) Operation time, operative blood loss and postoperative hospital stay. (2) Visual analogue scale (VAS), erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were recorded preoperatively and at the end of follow-up. (3) Neurological function: ASIA grade was evaluated preoperatively and at the end of follow-up. (4) Complications were recorded postoperatively and during the follow-up.

Imaging outcomes: (1) Cobb angle: the angle between the upper endplate of the upper vertebral body and the inferior endplate of the inferior vertebral body was defined as Cobb angle. The Cobb angle of preoperative, postoperative and last follow-up were all measured on the lateral X-ray, respectively. (2) Bone graft fusion time is checked according to the CT scan during the follow-up, the criterion of bone graft fusion reported by Bridwell et al. [17] was used. Bridwell et al. divided the graft fusion into four grades. Grade I: Fusion with remodeling and trabeculae. Grade II: Graft intact, not fully remodeled and incorporated though. No lucencies. Grade III: Graft intact, but a definite lucency at

the top or bottom of the graft. Grade IV: Definitely not fused with resorption of bone graft and with collapse. Grade I and Grade II were defined as bone graft fusion in this study.

2.6. Statistical analysis

Matched *t*-test was used for intra-group comparison of normally distributed quantitative data and independent samples *t*-test was used for the inter-group comparison. The comparison of disordered qualitative data (e.g. sex, abscess or not) was performed by Chi-square test, and the comparison of non-normally distributed quantitative data (e.g. age, follow-up time and bone graft fusion time) and ordered qualitative data (e.g. ASIA grade) was performed by Mann-Whitney *U* test. SPSS 22.0 software was used for statistical analysis. *P* < 0.05 was considered to be the significant difference.

3. Results

3.1. Clinical features of patients

A total of 61 patients were included, including 35 cases in non-structural bone graft group and 26 cases in structural bone graft group. There was no significant difference in age, gender and paravertebral abscess between the two groups (*n.s.*, no significant). The follow-up time of structural bone graft group was longer than that of non-structural bone graft group (*P* < 0.001). The comparisons of preoperative clinical features between the two groups were shown in Table 1.

3.2. Clinical outcomes

Compared with structured bone graft, the operation time in non-structured bone graft was shorter and the operative blood loss was less (*P* < 0.05), but the hospital stay was longer (*P* < 0.05). The preoperative ESR of non-structural bone graft group was lower than that of the structural bone graft group (*P* = 0.003) and the CRP at the end of follow-up was higher than that of the structural bone graft group (*P* = 0.005). However, VAS score and CRP were both significantly improved at the end of follow-up in the two groups (*P* < 0.05). Comparisons of clinical outcomes between the two groups were shown in Table 2.

3.3. Imaging outcomes

The Cobb angle was corrected in both groups after operation and has some loss during the follow-up. The correction of Cobb angle in the structural bone graft group was larger than that in the non-structural bone graft group (*P* = 0.012), but the loss of Cobb angle in the structural bone graft group was also significantly higher than that in the non-

Table 1
Comparison of preoperative clinical features between the two groups.

Clinical features	Structural bone graft (N = 26)	Non-structural bone graft (N = 35)	<i>P</i> value
Age (year) ^a	42 (22–58)	44 (18–73)	<i>n.s.</i>
Gender ^b			<i>n.s.</i>
Male	11 (42.3%)	21 (60%)	
Female	15 (57.7%)	14 (40%)	
Paravertebral abscess ^b			<i>n.s.</i>
Yes	18 (69.2%)	24 (68.6%)	
No	8 (30.8%)	11 (31.4%)	
Follow-up time (month) ^a	33.5 (16–56)	18 (13–28)	< 0.001

^a Data was presented as median (range) and Mann-Whitney *U* test was performed.

^b Data was presented as number (percentage) and Chi-square test was performed.

Table 2
Comparison of clinical outcomes between the two groups.

Clinical features	Structural bone graft (N = 26)	Non-structural bone graft (N = 35)	P value
Operation time (min) ^a	245.4 ± 56.8	200.6 ± 46.4	0.001
Operation blood loss (ml) ^a	653.9 ± 420	442.9 ± 382.2	0.045
Hospital stay (d) ^a	12.3 ± 3.1	15.7 ± 7.1	0.028
Preoperative VAS ^b	6 (3–8)	5 (4–8)	0.275
Last follow-up VAS ^b	1 (0–5) ^c	1 (1–3) ^c	0.155
Preoperative ESR (mm/h) ^a	49.2 ± 23.6	32.9 ± 16.9	0.003
Last follow-up ESR(mm/h) ^a	13.5 ± 9.8 ^c	13.4 ± 4.3 ^c	n.s.
Preoperative CRP (mg/L) ^a	27.4 ± 20.4	24.7 ± 23.8	n.s.
Last follow-up CRP (mg/L) ^a	6.2 ± 5.2 ^c	11.6 ± 8.1 ^c	0.005

^a Data was presented as mean (SD) and Student *t*-test was performed.
^b Data was presented as median (range) and Mann-Whitney *U* test was performed.
^c *P* < 0.05 compared with preoperative.

Table 3
Comparison of imaging outcomes between the two groups.

Clinical features	Structural bone graft (N = 26)	Non-structural bone graft (N = 35)	P value
Preoperative Cobb angle (°) ^a	20.4 ± 11	18.0 ± 7.4	n.s.
Postoperative Cobb angle (°) ^a	6.8 ± 3.9 ^c	10.6 ± 6.0 ^c	0.008
Last follow-up Cobb angle (°) ^a	10.8 ± 4.7 ^d	11.9 ± 6.0	n.s.
Correction of Cobb angle (°) ^a	13.6 ± 10.9	7.5 ± 7.7	0.012
Loss of Cobb angle (°) ^a	4.0 ± 3.5	1.3 ± 0.4	< 0.001
Bone graft fusion time (month) ^b	8.5 (4–16)	6 (4–8)	< 0.001

^a Data was presented as mean (SD) and Student *t*-test was performed.
^b Data was presented as median (range) and Mann-Whitney *U* test was performed.
^c *P* < 0.05 compared with preoperative.
^d *P* < 0.05 compared with postoperative.

structural bone graft group (*P* < 0.001). The median bone graft fusion time in the non-structural and structural bone graft group were 6 (range 4–8) months and 8.5 (range 4–16) months, respectively (*P* < 0.001). Comparisons of imaging outcomes between the two groups were shown in Table 3.

3.4. Neurological function

At the end of follow-up, the preoperative ASIA grade of structural bone graft group was changed from grade C to grade D in 1 case and from grade D to grade E in 5 cases. In non-structural bone graft group, ASIA grade changed from grade C to grade D in 4 cases, from grade C to grade E in 2 cases and from grade D to grade E in 7 cases. Mann-Whitney *U* test showed no significant difference between the two groups in the ASIA grade at the end of follow-up (n.s.) (Shown in Table 4).

Table 4
Comparison of neurological function between the two groups.

Group	Preoperative ASIA	Postoperative ASIA				
		A	B	C	D	E
Structural bone graft (N = 26)	A	0	0	0	0	0
	B	0	0	0	0	0
	C	0	0	0	1	0
	D	0	0	0	0	5
	E	0	0	0	0	20
Non-structural bone graft (N = 35)	A	0	0	0	0	0
	B	0	0	0	0	0
	C	0	0	0	4	2
	D	0	0	0	0	7
	E	0	0	0	0	22

* Mann-Whitney *U* test was performed, preoperative comparison between the two groups (n.s.), last follow-up comparison between the two groups (n.s.).

3.5. Complications

In the structural bone graft group, 9 cases had complications including 3 cases of liver function damage, 3 case of sinus formation, 2 cases of pulmonary infection and 1 case of urinary tract infection. There were 10 cases of postoperative complications in non-structural bone graft group, including 4 cases of liver function damage, 1 case of renal function damage, 2 cases of sinus formation, 2 cases of pulmonary infection and 1 case of urinary tract infection. Chi-square test showed that no significant differences was found in postoperative complications between the two groups (n.s.). All the complications were recovered after active treatment.

4. Discussion

In this study, the follow-up time of non-structural bone graft group was shorter than that of structural bone graft group, this may be related to that the technique of structural bone graft was quite mature and has been used in our department for a long time, but the non-structural bone graft technology has only been applied in recent years. It has been proved that the clinical symptoms and Cobb angle would not significantly change after bone graft fusion [18]. In this study, all patients achieved bone graft fusion during follow-up. Therefore, we think that the clinical efficacy of the two bone graft methods can be evaluated objectively and a reliable conclusion thus can be drawn.

The preoperative ESR of non-structural bone graft group was lower than that of structural bone graft group, this may be related to that we mainly apply non-structural bone graft technology to spinal tuberculosis with slight bone destruction in the early stage [13,14]. At the end of follow-up, the CRP of non-structural bone graft group was higher than that of structural bone graft group, which may be related to the shorter follow-up time of the former group. The pain symptoms, ESR and CRP in the two groups were all improved at the end of follow-up. This may be related to effective chemotherapy and rigid posterior internal fixation, the focus of spinal tuberculosis gradually absorbed and

tended to stabilize, and bone fusion was obtained in all patients at the end of follow-up [19].

We also found that the operation time was shorter and the operative blood loss was less in the non-structural bone graft group, which may have the following reasons: a) The surgeons have to do a series of tedious procedures such as harvesting iliac bone, pruning titanium mesh and trying model during structural bone graft [20], but in non-structural bone graft, they only need to crush the lamina, spinous process, transverse process and so on to make bone pellets [14]. b) Iliac bone graft and titanium mesh bone graft have a high requirement for the condition of bone grafting bed and so extensive bone removal is required during the operation, resulting in increased surgical time and intraoperative bleeding [9]. c) The iliac bone mass is large and the titanium mesh is large with sharp edge, so it may be difficult to implant [10], but the granular bone is small and it is convenient to implant [12]. d) The titanium mesh is serrated and is not easy to slip after implantation, so once the model is not satisfactory during the operation, it is difficult to take out [20]. The hospital stay in the non-structural bone graft group is longer than that in the structural bone graft group for the following reasons: a) The surgeon concerned about the lack of support force for the non-structural bone graft [12,13], and told the patient to stay in bed as much as possible for 5–7 days after the operation, thus prolonging the time of getting out of bed. b) This may be affected by medical insurance, hospitalization costs, preoperative examination and other factors.

In this study, we found that the correction of Cobb angle in non-structural bone graft was smaller than that in structural bone graft, which may be associated with the loose structure of granular bone affording weaker supporting force than that of cortical bone and titanium mesh [12–14]. Also, we found that loss of Cobb angle correction in the structural bone graft group was significantly higher than that in the non-structural bone graft group. Possible causes were analyzed as follows: a) After the iliac bone implantation, the bone fusion occurred only within several millimeters near the interface between the grafts and the recipient area. However, the center of the bone graft showed osteonecrosis, absorption or collapse over time due to lack of blood supply [21]. b) The elastic modulus of autogenous bone and titanium mesh differ and there was interfacial cutting effect between titanium mesh and bone graft bed, and it was easy to sink in titanium mesh under high stress [22,23]. Although the loss of Cobb angle correction occurred in both groups during the follow-up period, the loss of Cobb angle was very slight. Once bone fusion was achieved, this slight loss of kyphosis has little effect on clinical symptoms [18]. Our previous study also found that the slight loss of kyphosis after spinal tuberculosis surgery had no effect on bone graft fusion, spinal stability, and clinical symptoms [15]. On the other hand, there was no significant difference in the improvement of clinical symptoms between the two groups and this may indirectly confirm the above views.

In this study, we also found that the time of bone graft fusion in non-structural bone graft group was significantly shorter than that in structural bone graft group, which may be explained by following reasons: a) The contact area between granular bone and vertebral body was larger, which was beneficial to the infiltration of nutrients and the growth of neovascularization [12,13]. b) The implanted granular bone can induce the proliferation of peripheral bone mesenchymal cells, secrete bone morphogenetic protein and promote osteogenesis [24]. c) The implanted granular bone was squeezed, deformed with each other, and the local stress stimulated bone growth [25].

At the end of follow-up, it was found that the neurological function of both groups was improved, which may be related to the effective decompression of the spinal canal and correction of local malformation during operation [26]. We found that most of the postoperative complications of spinal tuberculosis surgery were liver dysfunction, sinus formation, urinary tract or pulmonary infection, this may be related to long-term chemotherapy, long hospitalization time, low immunity and so on [27]. However, there was no significant difference in the

incidence of complications between the non-structural bone graft group and the structural bone graft group, and all the complications were cured after active treatment, which also indicated the safety of the two methods in the treatment of single segmental thoracic tuberculosis.

We consider that the indications of one stage posterior debridement, non-structural bone graft and internal fixation for the treatment of single segment thoracic tuberculosis were as follows: a) Progressive aggravation of neurological impairment or paralysis. b) Progressive exacerbation of local instability or kyphosis. c) Single segmental thoracic tuberculosis with bony destruction less than 50% percent of the vertebrae height of. e) The tuberculosis lesion was mainly in the former column and the posterior column was not involved.

This study also had some limitations. Firstly, this was a single center retrospective study with small sample size. Secondly, the difference in follow-up time may cause some heterogeneity. Thirdly, surgeons may have different experiences in the two bone graft methods.

In conclusion, non-structural bone graft has less surgical trauma and shorter bone fusion time compared with structural bone graft in the surgical treatment of single segment thoracic tuberculosis. The two methods may achieve comparable clinical efficacy in alleviating symptoms, correcting kyphosis and improving neurological function for appropriate cases. Due to potential heterogeneity caused by the different follow-up time, we will continue to observe these cases in order to verify this issue.

Competing financial interests

The author(s) declare no competing financial interests.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Data statement

I wish to give a statement explaining why I am not linking to or uploading my research data. Data will be made available on request.

Ethical approval

61 patients with spinal tuberculosis surgery were approved by the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University and all patients were signed informed consent.

Author contribution

Guarantor of integrity of the entire study: Yun-sheng Ou.
 Study concepts: Xing Du and Yun-sheng Ou.
 Study design: Xing Du; Yong Zhu.
 Definition of intellectual content: Zeng-hui Zhao; Bin He.
 Literature research: Wei Luo; Jian-yu Hu.
 Data acquisition: Xing Du; Zeng-hui Zhao.
 Clinical studies: Xing Du; Qi-qi Peng.
 Data analysis: Xing Du; Zeng-hui Zhao; Wei Luo; Bin He.
 Statistical analysis: Xing Du; Wei Luo; Bin He.
 Manuscript preparation: Yong Zhu; Jian-yu Hu.
 Manuscript editing: Xing Du; Qi-qi Peng.
 Manuscript review: Xing Du; Yun-sheng Ou.

Conflicts of interest

No conflict of interest associated with this work.

Research registration number

The study have been registered in Chinese Clinical Trial Registry.

Clinical trial registration number: ChiCTR1800019109 (<http://www.chictr.org.cn>).

Guarantor

Yun-sheng Ou.

Sources of funding

The author(s) declare no sources of funding.

CRedit authorship contribution statement

Xing Du: Conceptualization, Data curation, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **Yun-sheng Ou:** Conceptualization, Methodology, Resources, Supervision, Validation, Writing - review & editing. **Yong Zhu:** Data curation, Formal analysis, Methodology, Resources, Writing - review & editing. **Zeng-hui Zhao:** Data curation, Methodology, Resources, Software, Writing - review & editing. **Wei Luo:** Formal analysis, Software, Writing - review & editing. **Bin He:** Formal analysis, Resources, Software, Writing - review & editing. **Qi-qi Peng:** Data curation, Software, Writing - review & editing. **Jian-yu Hu:** Data curation, Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijso.2019.04.002>.

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