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Quantitative analysis of local bone graft harvested from the posterior elements during posterior spinal fusion in Adolescent Idiopathic Scoliosis patients

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STRUCTURED ABSTRACT

Objective: This study analyses the quantity of local bone graft obtained from
different anatomical parts of the posterior elements during corrective surgery for Adolescent Idiopathic Scoliosis patients.
Summary of background data: Locally harvested autogenous bone graft eliminates possible donor site morbidity and has all the important basic bone graft properties such as osteoinductivity, osteogenicity and osteoconductivity. Its usage was reported to be adequate to achieve fusion but none had quantifies the amount of local bone graft harvested.
Methods: Total of 40 AIS patients were recruited in the study. All posterior spinal fusion surgeries were performed by the same dual surgeons and same anesthetist with a single observer collecting and measuring bone grafts harvested. The bone grafts harvested from each respective posterior element (spinous processes, laminas, facets and transverses processes) and measured accordingly.
Results: There were 36 females and 4 males. Amongst cases recruited, there were 32% Lenke 1, 28% Lenke 2, 8%Lenke 3, 22%Lenke 5 and 10% Lenke 6. Total thoracic levels involved were 333, whereas lumbar levels were 81. The mean total weight of bone graft obtained per case was 36.5 ± 13.7 g. The total weight of lumbar bone graft to the number of lumbar fusion levels (4.5 ± 1.2 g/fusion level) was significantly higher than the total weight of thoracic bone graft to the number of thoracic fusion levels (3.2 ± 1.2 g/fusion level). The amount of bone graft was obtained was highest from lumbar spinous process (42%), followed by thoracic spinous process (32%), lumbar lamina (29%), lumbar facet (28%), thoracic lamina (25%), thoracic facet (22%), and thoracic transverse process (21%).
Conclusions: Lumbar vertebra provided more bone graft than thoracic vertebra. Spinous processes contributed the highest amount of local bone graft in the thoracic and lumbar spine.

1. Introduction

The main aim of Posterior Spinal Fusion (PSF) surgery for Adolescent Idiopathic Scoliosis (AIS) is to achieve a good and solid fusion of the spine. This can be achieved by advocating various techniques which utilizes autograft, allograft, synthetic bone substitutes or bone morphological proteins (BMP).[1–4] Autograft can be harvested from a location different from the primary surgical site such as the ribs or iliac crest,[5,6] or from structures that are available to be harvested locally during surgery such as the spinous processes, laminas, facets and transverse procesesses.[7] Alternatively, allograft can be source of bone graft used to augment spinal fusion.[4,8] Some centers used synthetic bone substitutes or BMP as an adjunct to promote fusion in patients.[3,8–12] However, the usage of allograft, synthetic bone substitutes and BMP as the primary technique for spinal fusion is controversial and the usage of autograft remains as the preferred choice by many spine surgeons.

Compared to autograft harvested from a separate site such as the rib or iliac crest, locally harvested autogenous bone graft eliminates possible donor site morbidity. Local autogenous bone graft has all the important basic bone graft properties similar to donor autografts such as osteoinductivity, osteogenicity and osteoconductivity. It had been reported that the usage of local bone graft only was adequate to achieve fusion in PSF for AIS.[7] However, none had reported the quantity and amount of local bone graft that were harvested. This study analyses the quantity of local bone graft obtained from different anatomical parts of the posterior elements (spinous processes, laminas, facets and transverses processes) during corrective surgery for AIS patients.

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2. Materials and methods

2.1. Study design

Forty AIS patients who underwent instrumented PSF from October 2016 to January 2017 were prospectively enrolled into the study. The study was approved by our institutional ethical board (MECID. No: 20163-2257). Written informed consent was obtained from both the parents and patient. Inclusion criteria were all AIS diagnosed with Cobb angle of more than 45° who consented to participate in this study. All non-idiopathic scoliosis, revision scoliosis cases and those not agreeable to participate for this study were excluded from this study. There were no conflict of interest between the authors.

2.2. Demographic and operative data

The following demographic data were collected preoperatively i.e. age, gender, height, weight, Body Mass Index (BMI), Lenke curves type. Intra-operatively, the following data were recorded; number of thoracic fusion levels, number of lumbar fusion levels, number of screws used, duration of surgery, total blood loss, wound size. The amount of local autogenous bone graft acquired from the following anatomical structures were also recorded i.e. thoracic spinous process, thoracic transverse process, thoracic lamina, thoracic facets, lumbar spinous process, lumbar lamina and lumbar facets.

2.3. Surgical procedure

All cases were operated by same dual surgeons, same anesthetist, and a single observer collected, measured and processed all bone graft obtained. Local bone graft was harvested at the specific stage of surgical procedures during PSF surgery. The local autogenous bone graft was harvested mainly during the following surgical stages as stated in the Table 1.

2.4. Bone graft data collection and preparation process

Each bone graft harvested was collected and categorized according to their origin: thoracic transverse process, thoracic facet, thoracic spinous process, thoracic lamina, lumbar facet, lumbar spinous process and lumbar lamina (Fig. 1). Soft tissue from the surface of the bones were removed and separated into a specific labelled gallipot. All bone graft was measured using an electronic weighing scale (CQT 2601, Adam Equipment™ (d = 0.1 g)) (Fig. 2). The values were documented according to the origin for the bone graft and recorded in excel sheet. All measurements were later calculated according to per segment weight and percentage. Bone grafts were then morselized into small pieces and were laid posteriorly over the raw posterior spinal region shown in Fig. 3.

2.5. Power analysis and sample size

As there were no previous studies done on bone graft amount, a pilot study recruiting 10 subject in each group was carried out to calculate the sample size for this study. By using the mean difference of per segment Thoracic Spinous Process (6.92) and Thoracic Lamina (5.36), we obtained 0.9 of effect size and 80% power of study, a statistical power analysis indicated that a minimum sample size of 40 subjects were needed.

Table 1
Summary of surgical stages and bone graft harvested site.

Surgical Stage	Bone graft harvested site
Pedicle screws insertion	Thoracic transverse processes
Release before correction	Thoracic facet joints, lumbar facet joints, all spinous processes
Corticotomy of lamina after final correction	All lamina

2.6. Statistical analysis

All the data were analyzed using the Software Statistical Package for the Social Science version 23.0 for Windows (SPSS, Chicago, IL). One-way ANOVA was used to compare difference between different groups of bone graft followed by Pairwise Comparison using Dunnet T3 method. Pearson Correlation Coefficient was used to determine correlation between bone graft and height, weight and BMI of patients.

3. Results

Among 40 AIS patients, there were 36 females (90%) and 4 males (10%). Mean age was 15.8 ± 3.8. Preoperatively scoliosis was classified according to Lenke classification, with Lenke 1 (32%), Lenke 2 (28%), Lenke 3 (8%), Lenke 5 (22%), and Lenke 6 (10%). There were 6 cases where only thoracic fusion was performed. The mean body weight was 47.7 ± 9.9 kg with the mean height of 157.5 ± 6.8 cm and the mean Body Mass Index (BMI) was 19.2 ± 3.6 kg/m^2. The mean number of thoracic fusion levels and lumbar fusion levels were 8.8 ± 3.2 and 2.7 ± 1.2 respectively. The mean numbers of screws inserted per case were 13.7 ± 2.7. All cases operated with a mean operation duration of 132.0 ± 35.2min. The mean blood loss was 882 ± 397.3 mL with the mean wound size was 29.9 ± 6.7 cm (Table 2).

The mean weights of bone graft harvested from the various anatomical sites were illustrated in Table 3. The mean total weight of bone graft obtained per case was 36.5 ± 13.7 g. The mean weight of bone graft harvested from spinous processes was 12.6 ± 4.4 g. The mean weight of bone graft harvested from transverse processes was 5.0 ± 2.7 g. Whereas the mean weight of bone graft harvested from lamina was 9.7 ± 4.5 g and the facet joints was 9.2 ± 4.3 g.

The mean weight of bone graft per segment harvested from the various anatomical sites was illustrated in Fig. 4. In the lumbar spine, the highest contribution of bone graft was from the spinous processes (42.2%). This was followed by the laminae (28.9%) and facet joints (28.9%). In the thoracic spine, the highest contribution was from the spinous processes (32.3%), followed by the laminae (25.8%), facet joints (22.6%) and transverse processes (19.3%). On average, the thoracic and lumbar spine provided 3.1 ± 1.2 g and 4.5 ± 1.2 g per fusion level respectively (Fig. 4). The ratio of total weight of bone graft (thoracic, 26.5 ± 10.7 g) to the number of thoracic fusion levels (8.8 ± 3.2) was 3.2 ± 1.2 g/fusion level. This was in comparison with the ratio of total weight of bone graft (lumbar, 10.0 ± 6.6 g) to the number of lumbar fusion levels (2.7 ± 1.2), which was 4.5 ± 1.2 g/fusion level. By using Independent *t*-test, the significant difference per fusion level was determined. There is highly significant difference per fusion level ($p < 0.001$) between thoracic and lumbar (Mean Difference: 1.38; 95% CI: 1.921, −0.843).

One-way ANOVA analysis was carried out to determine difference between groups, as shown in Fig. 5. Significant difference were found between Thoracic Spinous Process versus Thoracic Facet ($p = 0.003$), Thoracic Spinous Process versus Thoracic Transverse Process ($p < 0.001$), Thoracic Spinous Process versus Lumbar Spinous Process ($p = 0.012$), Thoracic Facet versus Lumbar Lamina, Thoracic Transvers Process versus Lumbar Facet ($p = 0.001$), Thoracic Lamina versus Lumbar Spinous Process ($p < 0.001$), Lumbar Spinous Process versus Thoracic Facet ($p < 0.001$), Lumbar Spinous Process versus Thoracic Transverse Process ($p < 0.001$), Lumbar Spinous Process versus Thoracic Lamina ($p < 0.001$), Lumbar facet versus Thoracic Facet and Transverse process ($p = 0.001$) and Lumbar Lamina versus Thoracic Transverse Process ($p = 0.005$).

Pearson Correlation test was carried out to determine correlation

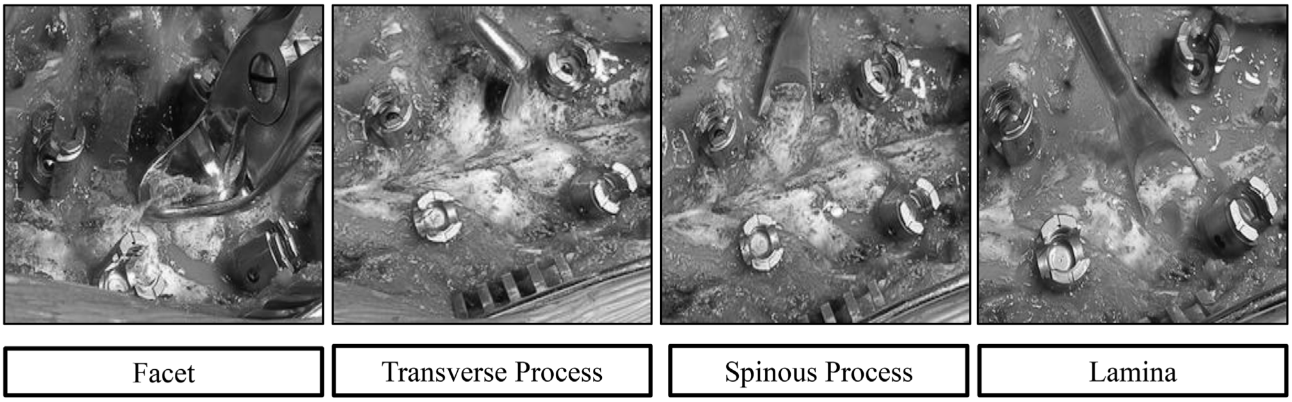


Fig. 1. The anatomical location of local bone graft harvesting.

between weight of bone graft weight in the thoracic and lumbar spine versus height, weight and Body Mass Index (BMI). There was no significant correlation noted (Table 4).

4. Discussion

There are various spinal fusion techniques used which utilizes local or donor autografts, allografts, synthetic bone substitutes or BMP.[1–4] However, each technique carries their own advantages and disadvantages. Allografts is the least popular due to the risk of transmission of infectious disease, the risk of contamination leading to surgical site infection and the lack of availability.[4,8] Bone substitutes such as synthetic porous ceramic (tricosite) or demineralized bone matrix can be used as an adjunct to the local bone graft.[8,9] However, it acts mainly an osteoconductive material and lack of osteoinductivity. Moreover, synthetic bone substitutes add to the cost of the surgery but with uncertain advantage to the outcome of fusion. This limits it widespread usage.[2,13] Recently, the usage of BMP for spine surgery had gained much attention due to its possible adverse reaction of heterotopic ossification, osteolysis, seroma/hematoma, infection, arachnoiditis, dysphagia (anterior cervical surgery), increased neurological deficits (myelopathy, radiculopathy), retrograde ejaculation, and cancer.[14]

Autogenous bone graft using iliac crest had been the "gold standard" for source of bone graft for spinal fusion surgeries.[3,6,13] It consists of all the basic properties of a good bone graft which are osteoinductivity, osteogenicity and osteoconductivity. However, the iliac crest bone graft harvesting is not without its problems. This procedure can be associated with possible donor site complications and morbidity such as donor site pain, wound breakdown, infection, donor site fracture, hematoma formation, arterial injury, increase blood loss and operative time.[13,15–19]

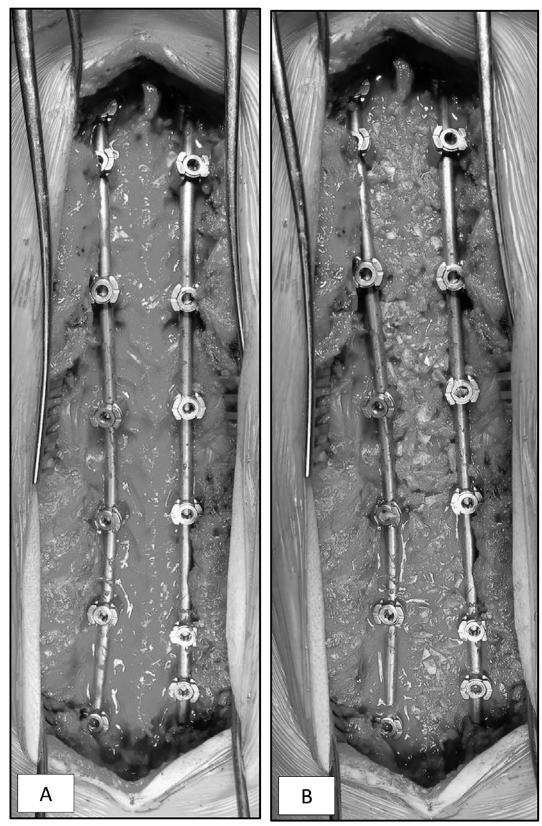


Fig. 3. (A) Posterior bone graft bed, (B) Bone graft laid on posterior spine.

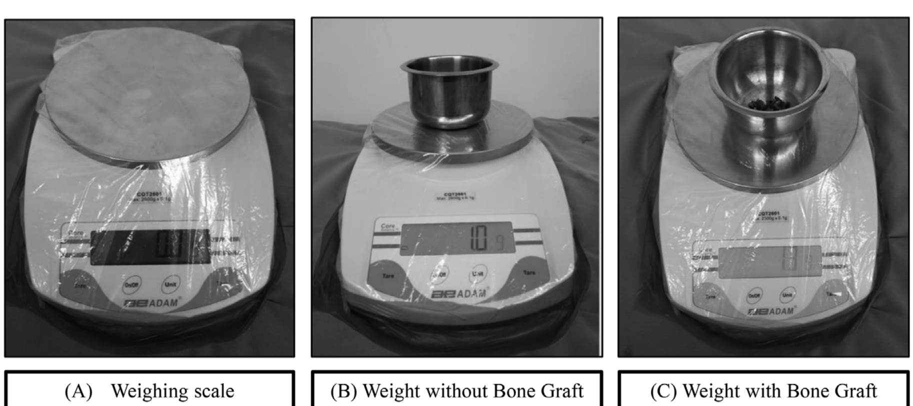


Fig. 2. The weighing scale preparation (A) Scale wrapped with sterile plastic, (B) Weighing Gallipot without bone graft, (C) Weighing Gallipot with bone graft.

Table 2
Demographic data and the operative data.

Demographics Data	
Variables	Mean (± SD) or n (%)
Age	15.8 ± 3.8
Sex (n (%)	
Male	4 (10)
Female	36 (90)
Weight (kg)	47.7 ± 9.9
Height (cm)	157.5 ± 6.8
BMI (kg/m^2)	19.2 ± 3.6
Lenke Type (n (%))	
1	13 (32)
2	11 (28)
3	3 (8)
4	0 (0)
5	9 (22)
6	4 (10)
Total	40 (100)
Operative Data	
Variables	**Mean (± SD)**
Number of thoracic fusion levels	8.8 ± 3.2
Number of lumbar fusion levels	2.7 ± 1.2
Number of screws	13.7 ± 2.7
Duration of surgery (mins)	132.0 ± 35.2
Total Blood Loss (mL)	882.4 ± 397.3
Wound size (cm)	29.9 ± 6.7

Local bone graft also has the properties of a good bone graft which are osteoinductivity, osteogenicity and osteoconductivity. Harvesting local bone graft can be surgically challenging as during this stage, when the local bone graft are actively being harvested, the raw exposed bony surfaces can bleed significantly leading to increase blood loss.[20] However, the authors used dual attending surgeon to reduce the operative time to minimize effective total blood loss.[21] Besides the possibility of increased blood loss during local bone graft harvesting, the quantity of local bone graft harvested may be a concern. Violas et al.[7] had reported that only local bone graft was adequate to achieve fusion in AIS posterior correction and arthodesis surgery but the amount of local bone graft harvested was not documented. Therefore, the quantity of local bone graft that can be obtained during PSF surgery for AIS surgery remains unknown and yet to be reported.

Carragee et al.[22] had quantified the volumes of local bone graft harvested in posterolateral lumbar fusion surgery and found that the local bone graft harvested was measured to be 25 cc (range, 12–36 cc). They concluded that large volumes of local bone can be harvested during posterolateral lumbar fusion surgery. This may be because of the larger amount of bone obtained from whole lamina which was removed during the decompression. In PSF surgery for AIS without osteotomy, none of the lamina is removed, therefore the amount harvested may be lesser. To the best of our knowledge, there were no studies reported the quantity of bone graft obtained locally during PSF surgery for AIS.

Our results showed that the average total local bone graft of 36.5 ± 13.7 g was obtained. The lumbar vertebra provided 4.5 ± 1.2 g/fusion level which was significantly ($p < 0.001$) more than the thoracic vertebra which provided 3.1 ± 1.2 g/fusion level. This concluded that lumbar vertebra provided more local bone graft than thoracic vertebra. This finding was expected as anatomically the lumbar vertebra has wider spinous processes, thicker laminas and larger facet joint when compared to the thoracic vertebra.

The highest amount of bone graft was obtained from thoracic and lumbar was spinous processes. Both thoracic spinous process and lumbar spinous process showed significant difference when compared to all thoracic elements ($p < 0.05$). The lowest amount of bone graft was obtained from thoracic traverse processes and it was significant when compared to all other sites of bone graft harvested ($p < 0.05$). However, when comparing the amount of bone graft obtained from the lumbar posterior elements, no significant difference ($p > 0.05$) was found between lumbar spinous process, lumbar lamina and lumbar facets, with each component contributed equally (42.2%, 28.9% and 28.9% respectively) to the total amount of lumbar bone graft.

This study also looks into the relationship between height, weight and BMI (Body Mass Index, kg/m^2) with the amount of bone graft harvested. It is hypothesized that, height of the patient will influence the amount of bone graft obtained. A study was done to determine relationship of body mass index at spine with height and weight but only showed partly associated with weight and height.[23] We found that there was no significant difference found between the weight of the thoracic and lumbar bone graft with patients' height, weight and body mass index (BMI).

The main limitation of this study was that there was no direct comparison between the quantity of local bone graft and the "gold standard" iliac bone graft. Another limitation was that there was no definite way to ascertain that the amount of bone graft harvested locally was adequate for fusion of the spine as there were no previous studies that looked into this for comparison. This study reported the preliminary findings of the quantity of local bone graft harvested and a follow up study that looked into the fusion rate will be needed. The number of patients may not be adequate to conclude on the relationship between height, weight and BMI with the amount of bone graft harvested.

5. Conclusion

In posterior spinal fusion surgery, lumbar vertebra provided more bone graft than thoracic vertebra. Spinous processes contributed the highest amount of bone graft in both thoracic (approximately one third) and lumbar (approximately half) spine when local bone graft was harvested.

Disclosures

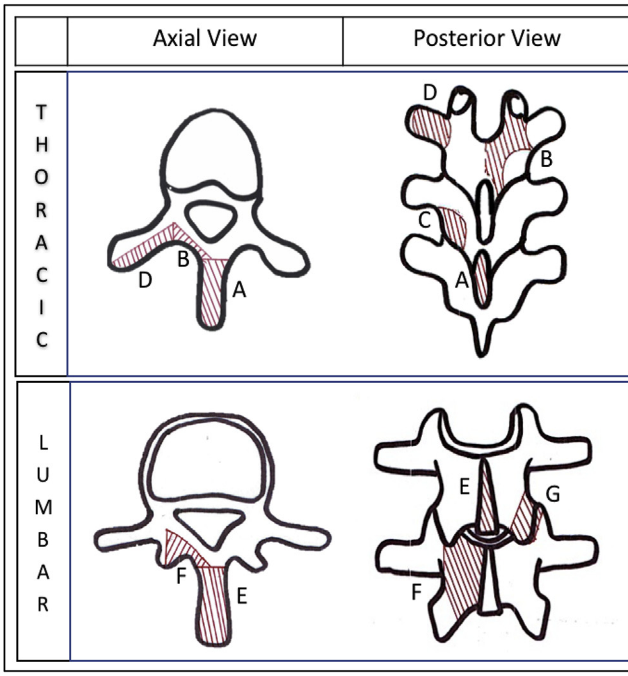
None.

Funding

None.

Table 3
The overall weight of bone graft and weight of bone graft per fusion level from different anatomical bone graft harvest site of the posterior elements.

Bone graft harvest site	Thoracic (g)		Lumbar (g)		Total (g)	
	Overall	Per fusion level	Overall	Per fusion level	Overall	Per fusion level
Spinous Process	8.6 ± 3.4	1.0 ± 0.4	4.0 ± 2.6	1.9 ± 0.6	12.6 ± 4.4	1.2 ± 0.4
Lamina	6.7 ± 3.3	0.8 ± 0.4	3.0 ± 2.6	1.3 ± 0.7	9.7 ± 4.5	0.9 ± 0.4
Facet	6.3 ± 3.3	0.7 ± 0.3	3.0 ± 2.2	1.3 ± 0.6	9.2 ± 4.3	0.8 ± 0.3
Transverse Process	5.0 ± 2.7	0.6 ± 0.3	nil	nil	5.0 ± 2.7	0.4 ± 0.2
Total	26.5 ± 10.7	3.2 ± 1.2	10.0 ± 6.6	4.5 ± 1.2	36.5 ± 13.7	3.4 ± 0.9



	Anatomical Area	Weight Per Level	Percentage
A	Spinous Process	1.0g	32.3%
B	Lamina	0.8g	25.8%
C	Facet	0.7g	22. 6%
D	Transverse Process	0.6g	19.3%
	Total Thoracic	3.1g	100%
E	Spinous process	1.9g	42.2%
F	Lamina	1.3g	28.9%
G	Facet	1.3g	28.9%
	Total Lumbar	4.5g	100%

Fig. 4. The contribution of bone graft harvested from each different anatomical site.

Conflicts of interest

None.

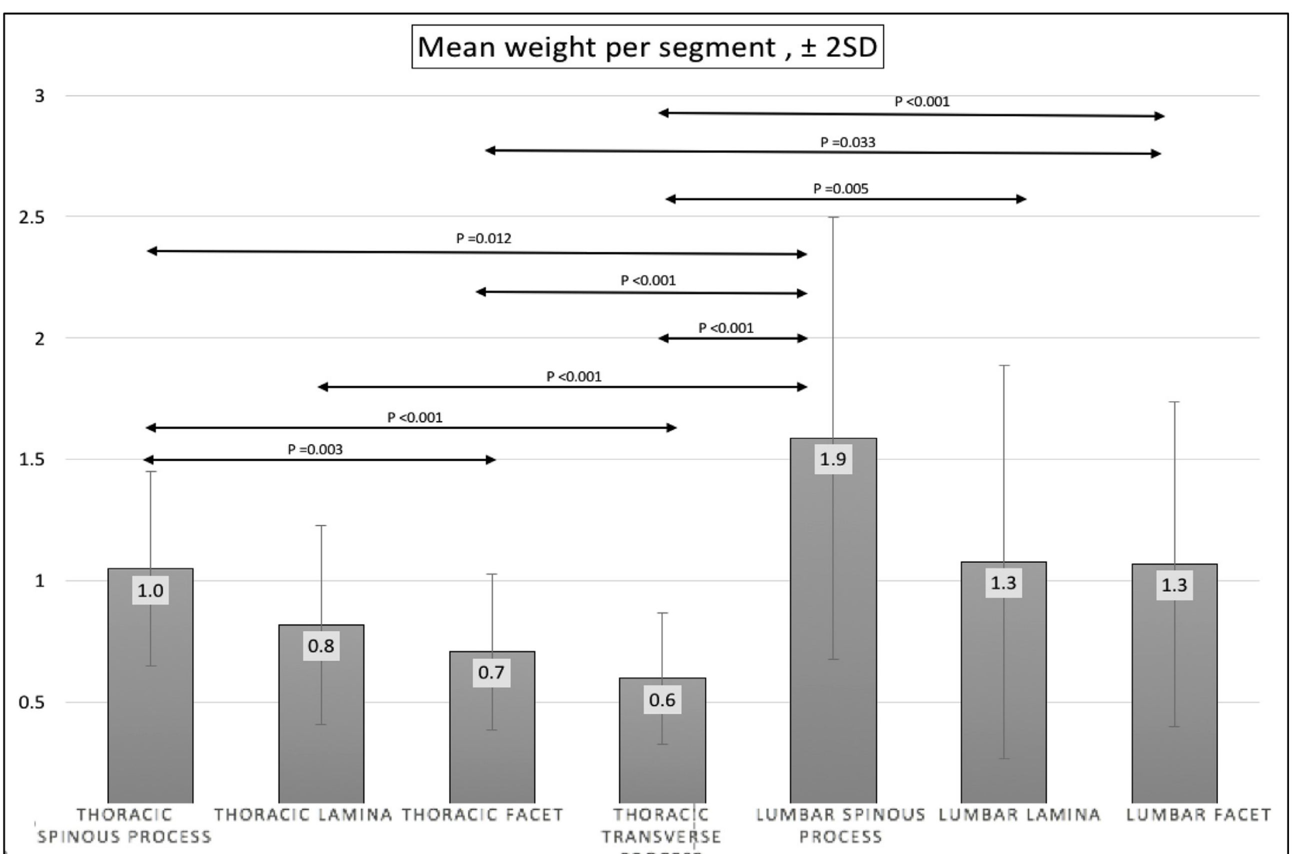


Fig. 5. The mean weight per segment and comparison between groups with significance difference using ANOVA one way analysis.

Table 4
The correlation between the weight of thoracic and lumbar bone graft with patients' weight, height and BMI.

		Weight (kg)	Height (cm)	BMI (kg/m^2)
Overall weight of thoracic bone graft	r value	0.13	−0.022	0.16
	p value	0.412	0.893	0.340
Overall weight of lumbar bone graft	r value	−0.091	−0.078	−0.053
	p value	0.575	0.632	0.743
Weight of thoracic bone graft/segment	r value	0.15	−0.05	0.16
	p value	0.409	0.794	0.340
Weight of lumbar bone graft/segment	r value	−0.005	−0.27	−0.053
	p value	0.977	0.143	0.743
Overall weight of bone graft/segment	r value	−0.010	−0.070	0.029
	p value	0.953	0.669	0.858

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jor.2018.12.004.

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