Original Article

Preoperative three-dimensional simulation and clinical evaluation of *in-situ* bone harvesting in anterior cervical discectomy and fusion surgery

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Background: The supplemental harvesting of *in-situ* bone obtained from cervical vertebrae as cage-filling material in anterior cervical discectomy and fusion (ACDF) results in a good fusion outcome. This study aimed to further quantitatively evaluate the obtainable bone volume and clinical outcomes of cervical *in-situ* autogenous bone grafting based on a three-dimensional (3D) preoperative simulation.

Methods: This study included 78 patients who underwent single-level ACDF. Prior to the surgical procedure, a 3D simulated surgery was performed by constructing several cutting planes in the cervical vertebrae based on Mimics software. The volumes of the harvested *in-situ* bone graft, including the anterior lip, posterior osteophytes, and Luschka's joint volumes, were measured during the simulated surgery. Immediate postoperative computed tomography (CT) scans were performed to evaluate the efficacy of the preoperative planning. During the postoperative follow-up period, the neurological function and cervical fusion state were also evaluated.

Results: The average volume of the cage's bone graft groove was 373.1±74.4 mm^3, which was lower than that calculated in the preoperative planning (501.6±179.6 mm^3, $P<0.001$). In 88.5% (69/78) of the simulated surgery cases, the harvested bone met the volume of the cage's bone graft groove, aligning with the intraoperative scenario. Male patients, elderly patients, patients with lower surgical segments, and patients with higher-grade facet joint degeneration had a more sufficient availability of *in-situ* autologous bone. The mean follow-up time was 18.02±4.9 months. At the final follow-up, the pain and functional status scores of the patients had improved significantly following surgery ($P<0.05$).

Conclusions: Preoperative planning for ACDF using Mimics software was shown to be both feasible and accurate. The 3D simulated surgery revealed that the majority of patients could supply a sufficient volume of cervical autologous bone for intraoperative grafting. The comprehensive analysis of the *in-situ* bone harvesting in ACDF provided precise reference data for the clinical implementation.

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Introduction

The goal of anterior cervical discectomy and fusion (ACDF) is to achieve robust osseous fusion. Cloward first described anterior cervical decompression using an autologous iliac crest interbody graft in 1958 to maintain intervertebral disc height (1). Smith and Robinson later developed a technique using iliac crest bone blocks, which became the standard for many years (2). However, the occurrence of complications, such as donor site pain, following ACDF with bone grafting remains a major challenge (3). The Williams-Isu technique uses autologous bone obtained from cervical vertebral bodies as a bone graft material, and has a fusion rate similar to that of the Cloward technique (4,5). However, the use of autogenous bone has had controversial results, including poor fusion rates, decreased disc height, and limited improvement in neck pain (6).

Liu *et al.* (7) found that compared to the use of a pelvic bone graft alone, the use of the anterior lip and posterior osteophyte of the cervical spine in a polyetheretherketone (PEEK) cage produced superior radiographic results. However, the current harvesting method relies solely on the surgeon's expertise, and does not measure the precise volume of the local *in-situ* bone graft.

The use of preoperative three-dimensional (3D) simulated surgery to guide *in-situ* autograft harvesting in ACDF can improve decision making and reduce costs by decreasing the need for allografting. This study aimed to comprehensively analyze *in-situ* bone harvesting in ACDF in different populations. Additionally, it sought to determine if cervical *in-situ* bone grafting is sufficient to fill cages, and thus provide reference bone volume data for implementing autologous *in-situ* bone acquisition techniques in clinical practice. We present this article in accordance with the STROCSS reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1726/rc).

Methods

Patient selection and image acquisition

This retrospective cohort study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Guangdong Provincial People's Hospital (approval No. KY-Q-2022-112-01), and written informed consent was obtained from all participants. Cervical computed tomography (CT) and magnetic resonance imaging (MRI) scans were acquired from patients who were admitted to Guangdong Provincial People's Hospital for the purpose of diagnosing cervical spondylotic radiculopathy (CSR) or cervical spondylotic myelopathy (CSM). These patients were admitted to the Spine Surgery Department and subsequently underwent primary single-level ACDF surgery between January 2020 and December 2021. The CT scans were retrieved from the hospital's Picture Archiving and Communication System database and were retrospectively examined. Patients were excluded from the study if they had a history of spinal surgery, trauma, tumor, or severe osteoporosis, were pregnant, or were unwilling to provide consent (*Figure 1*). Patients were categorized based on the classification of cervical facet joint and intervertebral disc degeneration as determined by CT and MRI scans, respectively (8,9).

3D reconstruction and simulation data analysis

All patients underwent preoperative CT scans within a period of 1 to 3 months. The specific parameters of the CT scans were as follows: 120 kVp, 320 mA, 512×512 matrix, and a slice thickness of 1.0 mm. The resulting slices were saved in Digital Imaging and Communications in Medicine format and subsequently imported into Mimics

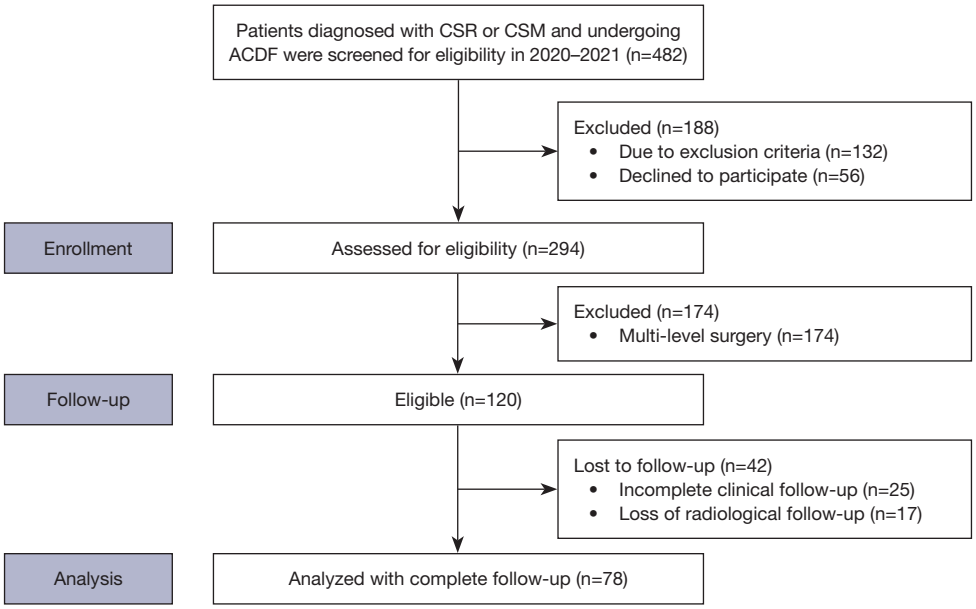

Figure 1 Patient selection flowchart. CSR, cervical spondylotic radiculopathy; CSM, cervical spondylotic myelopathy; ACDF, anterior cervical discectomy and fusion.

(version 21.0; Materialize, Leuven, Belgium) software for the 3D reconstruction of the geometric structure of the C2–C7 vertebrae. To simulate the process of polishing the vertebrae, the intervertebral disc, as well as the anterior and posterior longitudinal ligaments, were entirely excised from the surgical segments.

The measurement of the cage bone graft groove was acquired in accordance with the operating instructions for the intervertebral fusion device. Using the predetermined boundary conditions established during surgical simulation, the total amount of harvested volumes of the anterior lip and posterior osteophytes of the upper vertebral body, and the anterior and posterior osteophytes of the inferior vertebral body were computed. CT scans were conducted 1 week after the operation to determine the volume harvested in the actual surgery, and eliminate potential inaccuracies in the harvested bone volume calculation due to interbody fusion or cage subsidence. Following postoperative CT scans, the screws were reconstructed and subsequently removed from the 3D reconstruction model. Bone fusion following cervical spine surgery is characterized by the formation of bone bridges within the fused segments as observed on CT scans (10,11). To facilitate standardized comparison, the dimensions of the cage and screws were documented during the surgical procedure.

The modified Japanese Orthopaedic Association (mJOA), visual analog scale (VAS), and neck disability index (NDI) scores were used to assess the postoperative clinical outcomes. The volume of the cage and the amount of bone taken from each part of the cervical spine preoperatively and postoperatively were recorded for each patient. The amount of bone taken from each part of the cervical vertebrae was also calculated as a percentage of the volume of the cage.

Surgical simulation and boundary conditions

In the sagittal plane of the two-dimensional (2D) CT, the boundary conditions of the surgical simulation were defined as follows (*Figure 2A-2F*):

- Line A: the tangent line to the lowest point of the concave surface of the anterior edge of the upper vertebral body;
- Line B: the tangent line to the lowest point of the concave surface of the posterior edge of the upper vertebral body;
- Line C: the tangent line at the lowest point of the concave surface of the lower edge of the upper vertebral body;
- Line D: the tangent line at the lowest point of the concave surface of the superior margin of the inferior vertebral body;
- Area a: the intersection of Line A with Line C in

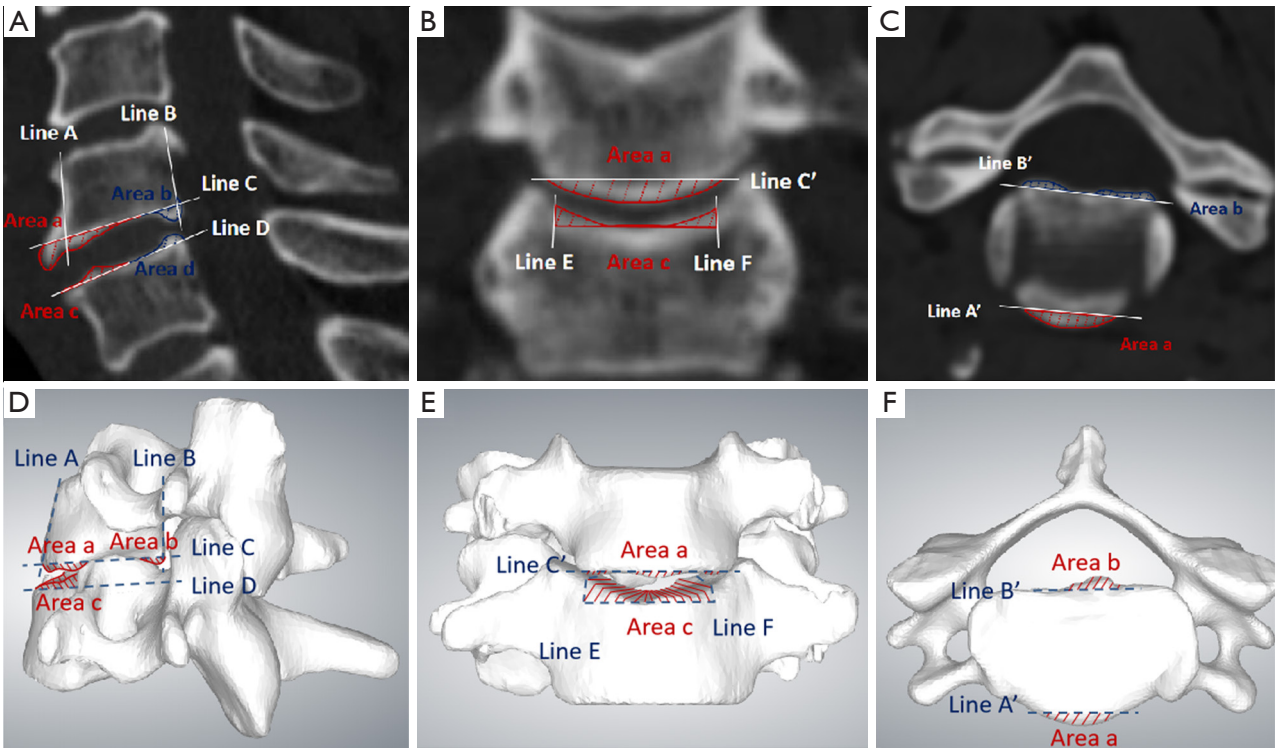

Figure 2 Illustrations of boundary definitions for surgical simulation in 2D and 3D CT reconstruction. (A) A sagittal image of 2D CT reconstruction. (B) A coronal image of 2D CT reconstruction. (C) A transverse image of 2D CT reconstruction. (D) A sagittal image of 3D CT reconstruction. (E) A coronal image of 3D CT reconstruction. (F) A transverse image of 3D CT reconstruction. 2D, two-dimensional; 3D, three-dimensional; CT, computed tomography.

the anterior edge of the upper vertebral body;

- Area b: the intersection of Line B with Line C in the posterior edge of the upper vertebral body;
- Area c: the intersection of Line D with the anterior edge in the lower vertebral body;
- Area d: the intersection of Line D with the posterior edge in the lower vertebral body.

While in the coronal and transverse plane of the 2D CT, Line E and Line F were defined as the lines connecting the medial sides of the bilateral uncinate joints.

All these lines were also labeled in 3D CT. Examples of the 3D CT reconstruction are provided in *Figure 3*.

Surgical procedures

Following the administration of general anesthesia, the patient was positioned in the supine posture. Subsequently, the appropriate cervical disc was identified using intraoperative fluoroscopy, and a transverse incision was made. The standard Smith-Robinson approach was then employed, and the ACDF surgical techniques were performed. After adequate visualization of the vertebral body and the disc, the anterior bony cribbing was removed using a rongeur. The Caspar screw was then disposed of in the midline of the upper and lower vertebral bodies of the disc to be removed, and the intervertebral space was gently dilated using the Caspar spacer. The disc was subsequently incised with a sharp blade and completely removed with a curette. When removing the anterior vertebral body, either a Kerrison rongeur or a high-speed burr was used to provide a better view of the posterior structures for exposure and manipulation. The disc and cartilaginous endplates were completely removed, and the bony encumbrances at the posterior aspect of the vertebral body were also removed using either a high-speed burr or a plate grinder to expose the posterior longitudinal ligament. A high-speed burr was used to polish the medial border of the uncovertebral joint, and a small curette or Kerrison rongeur was used to remove the remaining bony remnants for decompression of the intervertebral foramen.

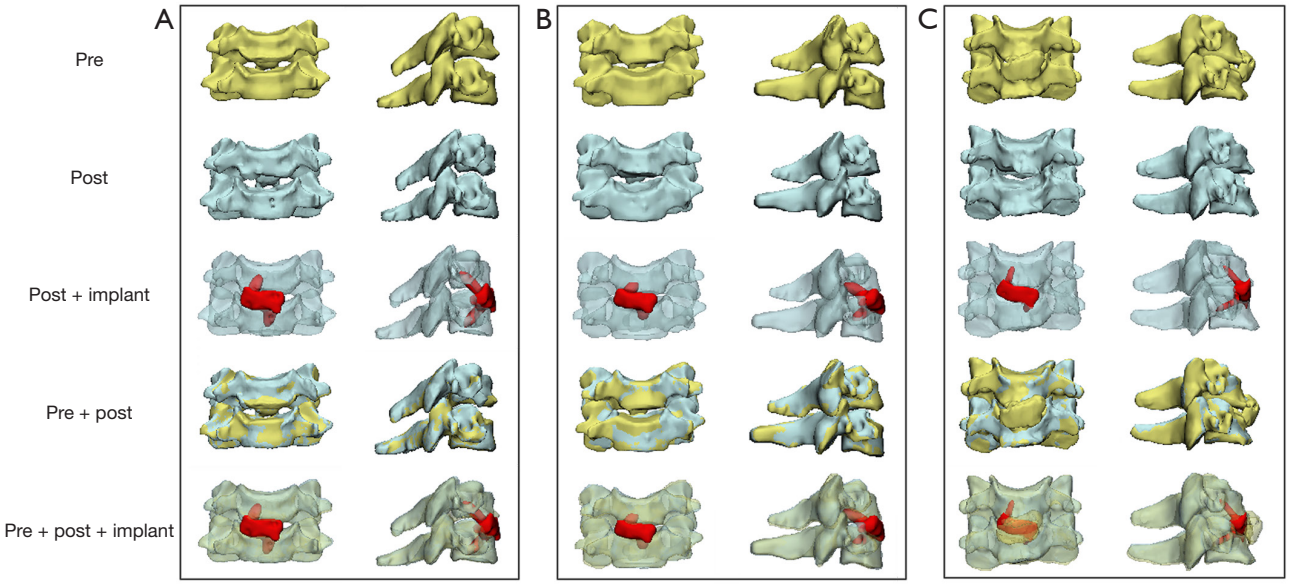

Figure 3 Examples of the pre, post, and merge images of the harvested bone grafting in the surgery. (A) The harvested bone volume matched the CgV. (B) The harvested bone volume was insufficient for the CgV. (C) The harvested bone volume was excessive for the CgV. Pre, preoperative; post, postoperative; CgV, cage's bone graft groove volume.

All intraoperative bone grinding operations were performed based on the preoperative surgical plan and identification of anatomical landmarks. *In-situ* bone fragments from the vertebral body were obtained using a Kerrison rongeur or a high-speed burr. Bone fragments were collected by a curette, and subsequently placed within the bone graft groove of the cage. The specification for the cage is zero-profile (self-locking) (Johnson & Johnson, New Brunswick, NJ, USA). The length of the operation, intraoperative blood loss, and perioperative complications were recorded.

Statistical analysis

All parameters are expressed as the mean ± standard deviation. To test the significance of the observed differences between the preoperative and postoperative parameters, a paired-sample *t*-test was employed in different sex groups. An analysis of variance was conducted to test differences among the subgroups in terms of age, surgical segments, cervical facet joint degeneration classifications, and cervical intervertebral disc degeneration classifications. To assess the inter-observer reliability, two researchers performed the boundary condition determinations and corresponding measurements independently. All statistical analyses were performed using SPSS version 21.0 (SPSS, Chicago, IL, USA), and a P value <0.05 was considered statistically significant.

Results

Demographic characteristics of the patients

In total, 78 patients, of whom 36 were male and 42 were female, were included in this study. The average age of the patients was 52.4±10.2 years. Among the participants, 50 were diagnosed with CSM, and 28 were diagnosed with CSR (*Table 1*). The average duration of the surgical procedure was 75.3 minutes (range, 62–98 minutes), while the mean blood loss was 49.2 mL (range, 33–71 mL).

Evaluation of the postoperative clinical effects

No perioperative complications were observed in the study. All patients were monitored for a minimum of 12 months, and the mean follow-up time was 18.02±4.9 months. At the final follow-up assessment, the postoperative mJOA (13.8±2.0 *vs.* 10.8±2.1), VAS (1.7±0.8 *vs.* 5.2±1.5), and NDI (0.102±0.054 *vs.* 0.218±0.083) scores had improved significantly (P<0.05) (*Table 1*). The fusion rate at the 1-year follow-up was 91.0% (71/78), and this rate increased to 96.2% (75/78) at the 1.5-year follow-up.

Table 1 Demographic characteristics of the patients

Characteristics	Data	P value
Number of cases	78	–
Gender		–
Male	36	
Female	42	
Age (years)	52.4±10.2	–
Operative time (min)	75.3 [62–98]	–
Blood loss (mL)	49.2 [33–71]	–
Diagnosis		–
CSM	50	
CSR	28	
mJOA score		<0.05
Preoperative	10.8±2.1	
Postoperative	13.8±2.0	
VAS		<0.05
Preoperative	5.2±1.5	
Postoperative	1.7±0.8	
NDI		<0.05
Preoperative	0.218±0.083	
Postoperative	0.102±0.054	
Height of cage (mm)	7.2±1.1	–
CgV (mm^3)	373.1±74.4	–

Data are presented as the number, mean ± standard deviation, or mean [range]. CSM, cervical spondylotic myelopathy; CSR, cervical spondylotic radiculopathy; mJOA, modified Japanese Orthopaedic Association; VAS, visual analog scale; NDI, neck disability index; CgV, cage's bone graft groove volume.

Parameter measurements

The construction of the 3D model was the most time-intensive aspect of the preoperative planning. On average, it took 28.4 minutes (range, 17–38 minutes) to complete the reconstruction of the 3D model. Additionally, the virtual ACDF planning took an average of 7.3 minutes (range, 5–9 minutes), while the parameter measurements took an average of 20.8 minutes (range, 15–38 minutes). The average height of the cage was 7.2±1.1 mm, and the cage's bone graft groove volume (CgV) was 373.1±74.4 mm^3. The total volume of the harvested bone in the simulated surgery (S-T) was 501.6±179.6 mm^3, which was smaller than total volume of the harvested bone in the actual surgery (A-T; 553.3±196.1 mm^3) (P>0.05). The surgical planning process indicated that the volume of the upper vertebral body's anterior lip (S-UA) would be 199.4±90.3 mm^3 and that of the posterior osteophyte (S-UP) would be 110.5±59.3 mm^3 (combined volume: 309.9±122.9 mm^3). Additionally, the combined volume of the anterior and posterior osteophytes in the lower vertebral body (S-LA and S-LP) was calculated to be 191.7±97.6 mm^3, with individual volumes of 98.8±57.6 and 92.9±56.4 mm^3, respectively (*Table 2*).

Comparing the preoperative and postoperative 3D CT reconstructions, the volumes of *in-situ* bone harvested from the upper and lower vertebral bodies during the actual surgery were calculated to be 347.7±141.0 and 205.5±101.4 mm^3, respectively (*Table 2*).

Subgroup analysis

The volume of available *in-situ* autologous bone was significantly greater in the lower surgical segments and in male patients, particularly in the S-UA and S-UP (P<0.05). Nevertheless, no significant difference was observed in the A-T in terms of the different surgical segments or genders (P>0.05).

The patients were categorized into three distinct age groups: the <45 years group (n=18); the 45–60 years group (n=38); and >60 years group (n=22). The elderly patients appeared to have more *in-situ* autologous bone available than the younger patients, and there was a significant difference in the S-UA and S-LA among the different age groups (P<0.05).

There were notable variations in the volumes of autologous bone obtained in various anatomical regions in both the simulated and actual surgery in terms of the different degrees of cervical facet joint degeneration (P<0.05). Conversely, in terms of the cervical intervertebral disc degeneration (Pfirrmann grading), no statistically significant difference was observed between the groups (P>0.05) (*Figure 4*).

Clinical application assessment

The S-UA/CgV was 55.2% (22.5–92.8%), the S-T/CgV was 132.5% (63.2–236.6%), and the A-T/CgV was 148.3% (65.4–252.1%). Nine patients (11.5%) had an insufficient actual harvest volume to completely fill the cage graft groove.

In terms of the different surgical levels, there was no

Table 2 Harvested bone volume in simulated surgery and actual surgery

Position	Harvested bone volume in simulated surgery			Total harvested bone volume in actual surgery (mm^3)
	Anterior lip volume (mm^3)	Posterior osteophytes volume (mm^3)	Combined volume (mm^3)	
Upper vertebral body	199.4±90.3	110.5±59.3	309.9±122.9	347.7±141.0
Lower vertebral body	98.8±57.6	92.9±56.4	191.7±97.6	205.5±101.4

Data are presented as the mean ± standard deviation.

statistical significance in the CgV (P>0.05). The S-T/CgV and S-UA/CgV were higher in the C6/7 segment compared to other simulated surgical segments (P<0.05), but also in the actual surgery (P<0.05) (*Figure 5*).

The S-T or A-T/CgV appeared to be greater in the older patients, but the difference was not statistically significant (P>0.05). Conversely, a statistically significant difference was found in the S-UA/CgV between the patients aged 45–60 years and those aged >60 years (P<0.05).

The mean CgV of the male patients (388.1±71.2 mm^3) was found to be slightly larger than that of the female patients (360.6±75.8 mm^3). The S-T/CgV and S-UA/CgV ratios were significantly higher in the male patients than the female patients (P<0.05). In addition, the A-T/CgV ratio was greater in the male patients (167.5%, 89.6–252.1%) than the female patients (125.2%, 65.4–233.8%) (P < 0.05).

In relation to the grading of facet joint degeneration, there was a significant difference in the S-T/CgV and A-T/CgV ratios among the different grades (P<0.05). In addition, the higher the grade of joint degeneration, the greater the volume of *in-situ* bone obtained in various anatomical regions (P<0.05). However, there was no statistically significant difference among the different groups in terms of the cervical intervertebral disc degeneration (Pfirrmann grading) (P>0.05).

Reproducibility

The results of the intra- and inter-observer reliabilities for all the measurement indices, as evaluated by a one-way random effects model, ranged from 0.91 to 0.96 and 0.84 to 0.93, respectively.

Discussion

3D CT reconstruction has been widely used in orthopedic preoperative planning, particularly in the fields of bone tumors and joint replacements (12-14). Recently, in the field of spinal surgery, research has been conducted on the morphology and imaging characteristics correlated with early vertebrae bone loss, and the improvement of postoperative neck pain and neural function of CSM (15,16). Yan *et al.* (17) used preoperative CT data to construct 3D models of the cervical ossification of posterior longitudinal ligament, and assessed the relevant parameters for intraoperative decision making. 3D CT reconstruction greatly improves the accuracy and safety of cervical spine surgeries involving precise procedures and high surgical risks. However, research on the use of 3D preoperative planning to calculate and design *in-situ* bone harvested in ACDF is limited. This study undertook a comprehensive analysis of the *in-situ* bone harvested in ACDF. Our findings provide valuable guidance for the decision-making process regarding bone grafting.

Several factors may influence intervertebral fusion, including sufficient local blood supply, a stable mechanical environment, an adequate presence of osteoblasts, a bone conduction matrix, and the presence of bone induction signals at the graft site. Similar to iliac bone, bone harvested from normal vertebrae contains bone marrow stem cells with osteogenic potential; thus, it is also suitable as bone graft material (18). In addition, the osteophytes of the vertebral body contain osteoblasts that have osteogenic potential. Notably, the anterior osteophytes have been shown to have the greatest number of osteoblasts and have the highest osteoblast/chondrocyte ratio (19). Numerous previous studies have shown that a PEEK cage filled with local *in-situ* bone graft material can lead to successful fusion without donor site-related complications, which means *in-situ* bone graft material is a well option (20,21).

The endplate serves as a crucial weight-bearing structure of the vertebral body, and any damage to its structure during surgical procedures may cause cage subsidence, even in vertebrae with normal bone mineral density (22,23). However, the procedure for *in-situ* bone harvesting in ACDF is currently based on surgeon experience, and

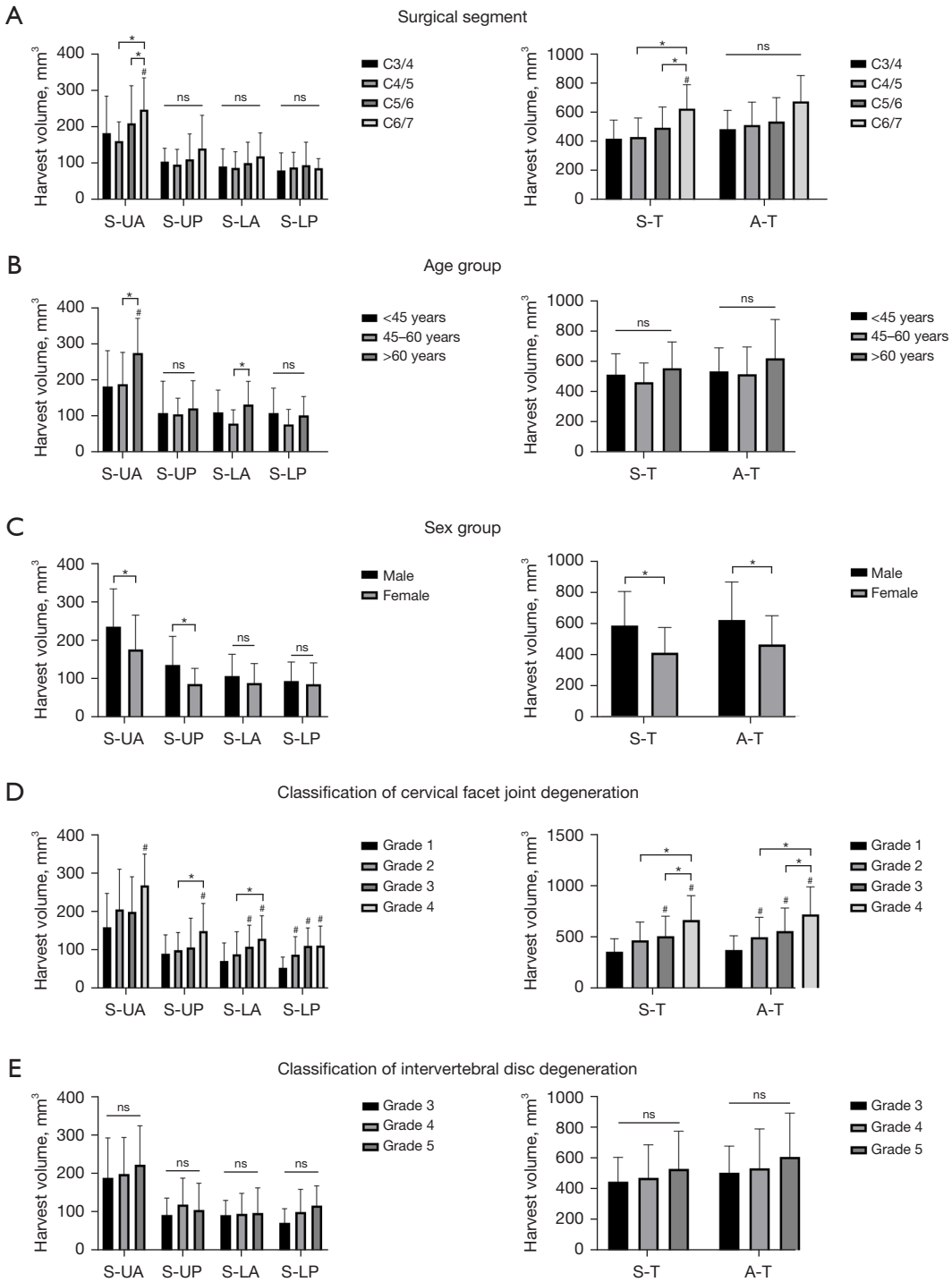

Figure 4 Comparison of the harvested bone volume in the simulated and actual surgery among the different subgroups. (A) Among the different surgical segments. (B) Among the different age groups. (C) Between males and females. (D) Among the different classifications of cervical facet joint degeneration (grades 1–4). (E) Among the different classifications of cervical intervertebral disc degeneration (Pfirrmann grading) (grades 3–5). *, P<0.05 indicates statistical significance between other groups except the first group. #, P<0.05 indicates statistical significance between the first group and other groups; ns, not significant. S, simulated surgery; UA, upper anterior lip; UP, upper posterior osteophyte; LA, lower anterior osteophyte; LP, lower posterior osteophyte; T, total harvest volume; A, actual surgery.

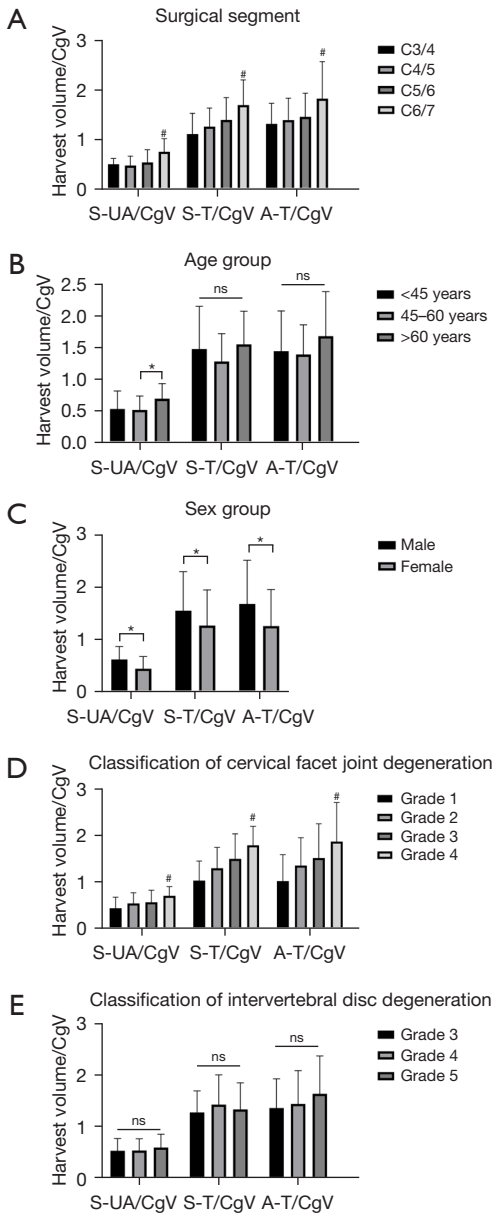

Figure 5 Comparison of the ratio of the harvested bone volume/CgV among the different subgroups. (A) Among the different surgical segments. (B) Among the different age groups. (C) Between males and females. (D) Among the different classifications of cervical facet joint degeneration (grades 1–4). (E) Among the different classifications of cervical intervertebral disc degeneration (Pfirrmann grading) (grades 3–5). *, P<0.05 indicates statistical significance between other groups except the first group. #, P<0.05 indicates statistical significance between the first group and other groups; ns, not significant. CgV, cage's bone graft groove volume; S, simulated surgery; UA, upper anterior lip; T, total harvest volume; A, actual surgery.

accurate supporting data are lacking. To the best of our knowledge, this report represents the first systematic quantitative investigation of the 3D morphological aspects associated with this procedure.

In this study, the anterior vertebral lip was the main source of bone graft material, and accounted for 61.7% of the available bone from the upper vertebrae, and was capable of filling 52.1% of the CgV. The size of the anterior lip is influenced by the anatomical attributes of the segment, and both the CT scan data and intraoperative observations showed that it varied based on the segment level. The average width and depth of the vertebral surface increase from C2 through C7, and the vertebral height of the posterior wall of the midsagittal plane from C3 to C7 ranges from 10.9 to 12.8 mm (24). In the present study, the younger patients and those with mild degeneration had fewer osteophytes on the anterior lip. More severe osseous degeneration means more osteophytes can be used as autologous bone, but the degree of intervertebral disc degeneration in the surgical segment may not be correlated with bony degeneration. We found that male patients, patients older than 60 years, patients who underwent surgery in the C6/7 segment, and patients with grade 4 facet joint degeneration had a greater availability of *in-situ* autologous bone. To optimize the surgical bone acquisition process, it is crucial to analyze the volume of the bone graft material provided by each vertebral body, and formulate customized surgical approaches for patients based on their specific surgical segments, ages, and degrees of facet joint degeneration. Regrettably, this important clinical consideration has not received adequate attention.

Cervical X-ray is the most frequently used method for evaluating cervical fusion (11,25). However, CT imaging provides a more comprehensive view of details that cannot be visualized by X-ray, enabling a more accurate assessment of bone bridge formation from various perspectives (10,26). Consequently, we used fused segmental bone bridge establishment on CT scans as a criterion for bone fusion. Of the patients, 88.5% in the cohort showed A-T fulfillment of the cage, which was consistent with the S-T calculation, and the fusion rate of our cohort was 91.0% at the 1-year follow-up, which is similar to that reported previously (20,21), and this rate increased to 96.2% at the 1.5-year follow-up.

It is not yet clear whether filling the cage's graft groove with bone graft material is necessary for successful bone fusion. Schröder *et al.* (27) showed that bone formation

occurred around and within the implant even without additional bone grafting in ACDF surgery. The incomplete filling of graft grooves in cages did not affect the fusion rates or clinical outcomes. Nine patients were found to have an inadequate volume of bone harvested during simulated surgery, as confirmed by postoperative CT, but had fusion results similar to the other patients. Factors contributing to this included their younger age, lower-level facet joint degeneration, surgery in the C3/4 segment, and limited bone availability from the inferior vertebral body. These findings are consistent with our surgical experience. S-T may have been smaller than A-T due to the surgeon's use of partial resection at the uncovertebral joint for decompression, or the decompression of the posterior edge of the upper and lower vertebral bodies. This difference was not statistically significant.

Additionally, the assessment of neurological function using the VAS, mJOA, and NDI scores showed postoperative improvement, indicating that the use of a PEEK cage with local *in-situ* bone grafting also enhances neurological outcomes in ACDF. Further research is being conducted to examine the link between fusion morphology, fusion rate, and clinical efficacy.

We also considered whether the use of cervical 3D CT reconstruction for preoperative planning affected the rate of ward turnover. With current technology, 3D reconstruction can be performed in about an hour, and took on average 28.4 minutes (range, 17–38 minutes) for the model and 7.3 minutes (range, 5–9 minutes) for the ACDF simulated surgery. This process does not significantly extend perioperative examinations but improves surgical efficiency. 3D CT reconstruction costs about $100, and thus is a worthwhile investment compared to allograft bone expenses. After practical operation and statistical verification, the 3D planning had a high feasibility, providing effective assistance for the preoperative preparation and bone grafting planning. The intra- and inter-observer reliability intra-class correlation coefficient (ICC) results were 0.91–0.96 and 0.84–0.93, respectively, indicating that the preoperative 3D CT reconstruction had a high repeatability.

The clinical and educational importance of the qualitative and quantitative 3D reconstruction is twofold. First, it can be integrated with surgical navigation systems, robot-assisted procedures, and artificial intelligence systems to aid in the development of surgical plans before surgery and can aid during surgical procedures (28). Second, it can serve as an effective training method for young doctors, facilitating the acquisition of surgical skills, reducing the learning curve, and minimizing the time required for training (29).

The current study had several limitations. First, due to the retrospective nature of the study, it has inherent biases, including selection bias. Second, the patient sample size was limited. Third, as the study was centered on CT-based techniques, it lacked a control group.

Conclusions

This study showed that the preoperative planning of ACDF based on Mimics software was feasible and accurate. The use of preoperative 3D CT simulated surgery indicated that the majority of patients could supply an adequate amount of cervical autogenous bone for intraoperative grafting during ACDF. This method could effectively guide the accurate harvesting of *in-situ* autografting in ACDF procedures and improve decision making.

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None.

Footnote

Reporting Checklist: The authors have completed the STROCSS reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-24-1726/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1726/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the

Institutional Review Board of Guangdong Provincial People's Hospital (approval No. KY-Q-2022-112-01), and written informed consent was obtained from all participants.

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