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Finite element analysis of retrograde superior ramus screw of pubis for the treament of pelvic anterior ring fracture

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Abstract

Background Retrograde superior ramus screw of pubis (SRSP) is a new kind of pelvic minimally invasive internal fixation apparatus developed by our team. The purpose of this study was to analyze the biomechanical stability of this new minimally invasive pelvic internal fixation device, and to provide this new device with theoretical basis for clinical application.

Methods The Tile C1.3 pelvic fracture model was established. The posterior ring was fixed in the same way with two sacroiliac screws. And the anterior ring was fixed with SRSP, reconstruction plate, minimal invasive subcutaneous internal fixator (INFIX) and hollow screw respectively, to establish the finite element model of fracture-internal fixation. Finite element analysis was used to analyze the deformation and Von Mises(V-M) stress distribution of different kind of fixation under three kinds of stress conditions: vertical self-weight load, anterior-posterior(A-P) compression and lateral compression.

Results Among the four-kind fixation models, all the maximum displacement of fracture site were significantly less than 2 cm, and the maximum V-M stress of internal fixation was lower than the yield stress of titanium metal (1050 MPa). The maximum displacement and V-M stress of total model/internal fixation in INFIX group were higher than those in the others under three stress conditions except for two cases, which were the maximum displacement of total model in SRSP group (0.26266 mm) under A-P compression and the maximum displacement of internal fixation in SRSP group (0.32588 mm) under lateral compression. The values of total model/internal fixation displacement and V-M stress distribution in SRSP group were similar to those of reconstructed plate group and hollow screw group. Furthermore, the stress distribution of SRSP group was more uniform from the stress nephogram.

Conclusion All four kinds of internal fixation can effectively repair Tile C1.3 pelvic fractures. Also fracture-fixation pelvis model were basically restore the normal mechanical conduction path, rebuilding overall stability of the pelvic ring with good static mechanical stability. The stress distribution of fracture-internal fixation model in SRSP group was more uniform. Compared with INFIX group, SRSP group was more advantageous in preventing excessive displacement of the fracture site, loosening and deformation of the internal fixation, etc.

Keywords Finite element analysis, Biomechanics, Retrograde superior Ramus screw of pubis, Pelvic fracture

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Introduction

The pelvis is a circular structure with complex anatomy. Compared with the posterior ring, the anterior ring of the pelvis has a weaker structure and is prone to fracture [1].The incidence of isolated pubic rami fractures after pelvic trauma is about 3-46% [2], and this type of fracture is often classified as stability injury. Fractures that included both anterior and posterior ring are more common, and about 96.8% of patients with rami pubis fractures were found to have concurrent injuries to the posterior pelvic rings [3]. In addition, 78% of the high-energy injuries have trans-pubic instability [4]. Indicating that in unstable pelvic fractures, anterior ring injury has a non-negligible proportion.

With the continuous development of surgical technology and the popularization of minimally-invasive concept in recent years, pelvic anterior ring fixation has also entered the era of minimally-invasive instead of the traditional metal plate fixation. At present, the mature treatment techniques for anterior ring fracture mainly include external fixation, screw fixation, internal stent fixation and percutaneous minimally invasive plate fixation, ect. However, most of them are unsatisfactory and scholars have never stopped exploring new internal fixation methods. To comply with the demand of the concept of minimally invasive, by using the principle of the intramedullary central fixing and combining the anatomical characteristics of the pubic symphysis, our research team designed and developed the retrograde superior ramus screw of pubis (SRSP), and has obtained the patent for utility model.

In our study, a 3D finite element model of TileC1.3 pelvic fracture model was constructed. We compared the stability of different internal fixation models and provide a theoretical basis for the new device -- SRSP.

Materials and methods

Pelvic model reconstruction

The pelvic computed tomography (CT) scan data in the Digital Imaging and Communications in Medicine (DICOM) format of a healthy adult volunteer (male, 25 years old, 175 cm height, 70 kg weight, and without previous traumatic or surgical history) were imported into Mimics21.0 (Materialise, Belgium). This study was approved by the Institutional Review Committee of our hospital with the informed consent of the patient. The 3D skeletal models including sacrum, bilateral ilium and the upper middle segment of femur were reconstructed. The STL files of bone were imported into Geomagic Wrap2021 software. The models were smoothed through remesh and local smoothing functions. Then the cancellous bone was created using integral migration function. The STP files of previous NURBS camber of skeletal models were imported into Solidworks2020 software to merge all those pelvic structures with the same origin. The articular cartilage locating at the sacroiliac joint, symphysis pubis, and hip joint were established using curve and stretching functions. Boolean operation was used to inspect there was no interference between every part. Imported into Ansys software, the pelvic model was meshed again.

Internal fixation models of anterior ring fracture

The healthy pelvic model was imported into the solidworks software, and the TileC1.3 pelvic fracture model which got left anterior pubic rami and ipsilateral sacral zone I fracture was established by cutting fracture line. Retrograde superior ramus screw of pubis, anterior ring plate, internal fixator (INFIX) and hollow screw for rami pubis (HSRP) were established in SOLIDWORKS software according to the location of the fracture line. Four different internal fixation models were established: (1) SRSP group: the anterior ring was fixed by retrograde superior ramus screw of pubis. (2) Plate group: the anterior ring was fixed by a 5-hole reconstruction plate. (3) INFIX group: the anterior ring was fixed by the minimal invasive subcutaneous internal fixator. (4) HSRP group: the anterior ring was fixed by a hollow screw of rami pubis. The posterior rings of the above models were uniformly fixed with two transsacral screws. (Fig. 1)

Meshing and material parameter settings

All four fixation models were meshed in Ansys software. The statistics of the four assembly elements and the total numbers of nodes are shown in Table 1.

It was assumed that the cortical bone, cancellous bone, plate, and screw were all continuous, isotropic, and uniform linear elastic materials. Based on previous research [5–7] and our experience, the elastic modulus and Poisson's ratio of various structural materials are shown in Table 2.

Boundary and loading conditions

Spring link was used to simulate the pelvic ligament reconstruction, and the parameters of the ligaments are shown in Table 3.

The following three engineering conditions were set for the four groups of fixation models. (1) Load in vertical direction (engineering condition 1): To mimic the standing position, the lower cross section of the femur on both sides were fixed and the pelvis was restricted in 6 directions of freedom. A vertical downward load of 500 N was imposed on the upper surface of the S1 vertebra to simulate the gravity of the upper part of the body. (2) Anterior-posterior(A-P) compression (engineering condition 2): Back of bilateral iliac spines were fixed and 250 N horizontal loads from forward to backward were applied to each side of the anterior superior iliac spine to simulate

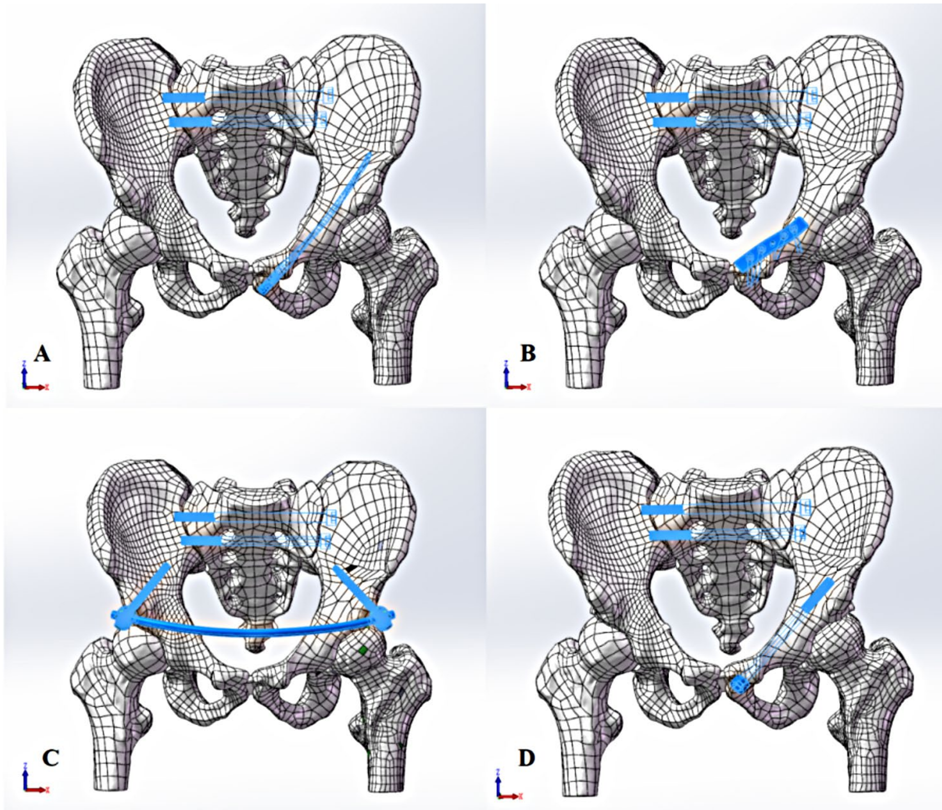

Fig. 1 Four different fracture-internal fixation models: (**A**) SRSP group: the anterior ring was fixed by retrograde superior ramus screw of pubis. (**B**) Plate group: the anterior ring was fixed by a 5-hole reconstruction plate. (**C**) INFIX group: the anterior ring was fixed by the minimal invasive subcutaneous internal fixator. (**D**) HSRP group: the anterior ring was fixed by a hollow screw of rami pubis. The posterior rings of the above models were uniformly fixed with two transsacral screws

Table 1 The nodes and elements of 5 kinds of FE models

Model	Nodes	Element number	Element size
healthy pelvis	688,552	372,282	
1 (SRSP group)	753,062	405,938	Bone part 2 mm
2 (Plate group)	826,160	445,969	
3 (INFIX group)	802,372	432,486	Internal fixaton 1 mm
4 (HRSP group)	759,304	410,819	

Table 2 Material properties of FE models

Materials	Elastic modulus(MPa)	Poisson ratio	Element type
Cortical bone	17,000	0.3	8 nodal 6 hedron
Cancellous bone	100	0.2	8 nodal 6 hedron
Plate/Screw	110,000	0.3	20 nodal 6 hedron
Articular cartilage	10	0.4	8 nodal 6 hedron
Pubic symphysis cartilage	5	0.45	8 nodal 6 hedron

the effect of anterior-posterior compression. (3) Load in horizontal lateral direction (engineering condition 3): Bilateral acetabular fossas were fixed and a 500 N horizontal lateral load was imposed to the left iliac tubercle to simulate the effect of lateral compression.

Furthermore, a sensitivity analysis was systematically conducted to evaluate the accuracy and efficiency of FE models by adjusting the optimal element size. Element sizes of 1 mm, 2 mm, and 3 mm for the bone were examined. The maximum von Mises stress on bone was set to be tested and the used convergence criterion was a change of $<5\%$ [8], which was considered to be mesh convergence. After the convergence measurement, the mesh size was determined to be 2 mm.

Evaluation criteria

Following data of total pelvic model and internal fixation were measured which comprised (1) the maximum displacements (2) the stress distribution and Von Mises (V-M) peak stress (3) displacements on both sides of the pubic fracture line (4) absolute value of separation in the horizontal direction of the fracture surfaces.

Table 3 Different parameters of pelvic ligaments

Ligaments	K(*N*/mm)	Element number	Elastic modulus(MPa)	Poisson ratio
Arcuate pubic ligaments	500	1 × 1	20	0.3
Superior pubic ligaments	500	1 × 1	20	0.3
Anterior sacroiliac ligaments	700	2 × 2	350	0.3
Sacrotuberous ligaments	1500	4 × 2	30	0.3
Sacrospinus ligaments	1400	4 × 2	30	0.3
Interosseous sacroiliac ligaments	2800	2 × 2	350	0.3
Posterior sacroiliac ligaments	1400	2 × 2	350	0.3

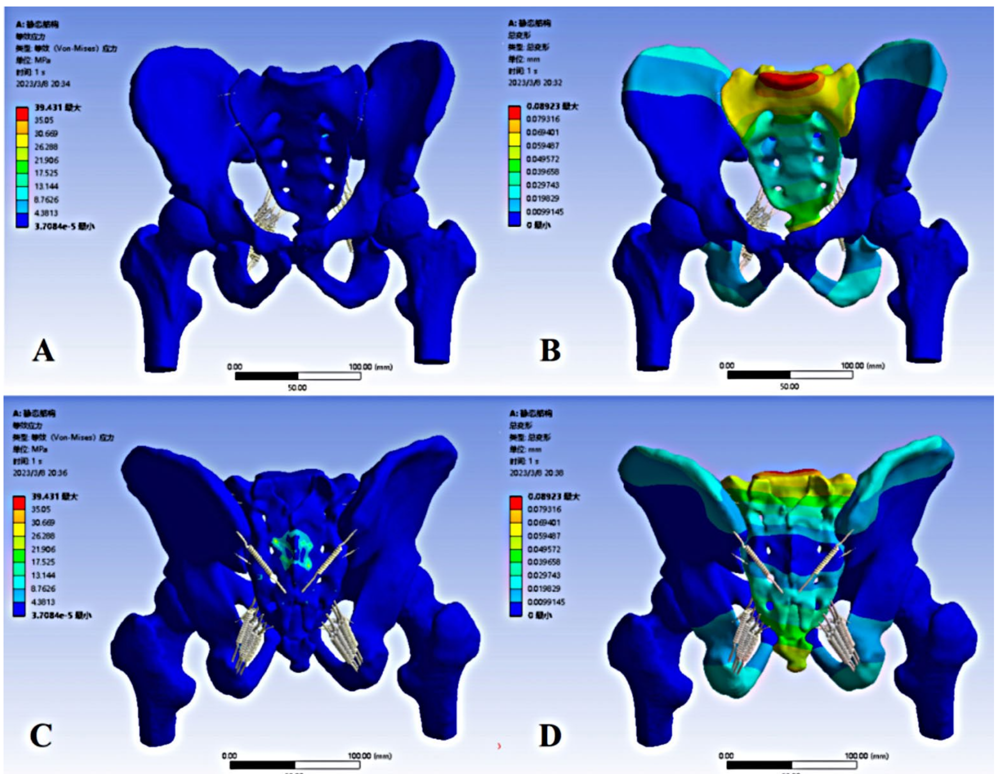

Fig. 2 The view of healthy pelvis model with the action of standing position: (**A**) Front view of V-M stress nephogram. (**B**) Front view of displacement nephogram. (**C**) Back view of V-M stress nephogram. (**D**) Back view of displacement nephogram

Results

It can be seen that the stress of the pelvic ring is transmitted from the top to bottom and the middle to sides, with a maximum stress of 39.431 MPa. The displacement (deformation) of the pelvis is roughly symmetrical from left to right and weakened in a wavy pattern along the iliac crest, with a maximum displacement of 0.08923 mm. The overall displacement of the pelvic model and the stress cloud map are essentially similar to that of the description in the relevant literature [9, 10], which also shows the validity of the pelvic finite element model. (Fig. 2)

Engineering condition 1

When simulating the vertical force of self-weight, it can be seen that the maximum displacement of overall model in each group, of which the highest value is 0.23161 mm (Fig. 5A), located in model INFIX. And the lowest is 0.045158 mm (Fig. 3A), located in model SRSP (Fig. 4). Among the maximum displacement of internal fixation in each group, the highest is 0.07138 mm (Fig. 5C) located in model INFIX. The lowest is 0.026625 mm (Fig. 3C), located in model SRSP. The maximum space of pubic bone broken ends is 36.8032×10^{-3}mm in model INFIX and the minimum space is 1.5289×10^{-3}mm in model HSRP (Table 4).

Among the maximum V-M stress value of overall model in each group, of which the highest is 526.77 MPa (Fig. 5B) located in model INFIX. And the minimum is 22.419 MPa (Fig. 6B), located in model HSRP. Among the maximum V-M stress value of internal fixation, the highest is 185.63 MPa (Fig. 5D) located in model INFIX.

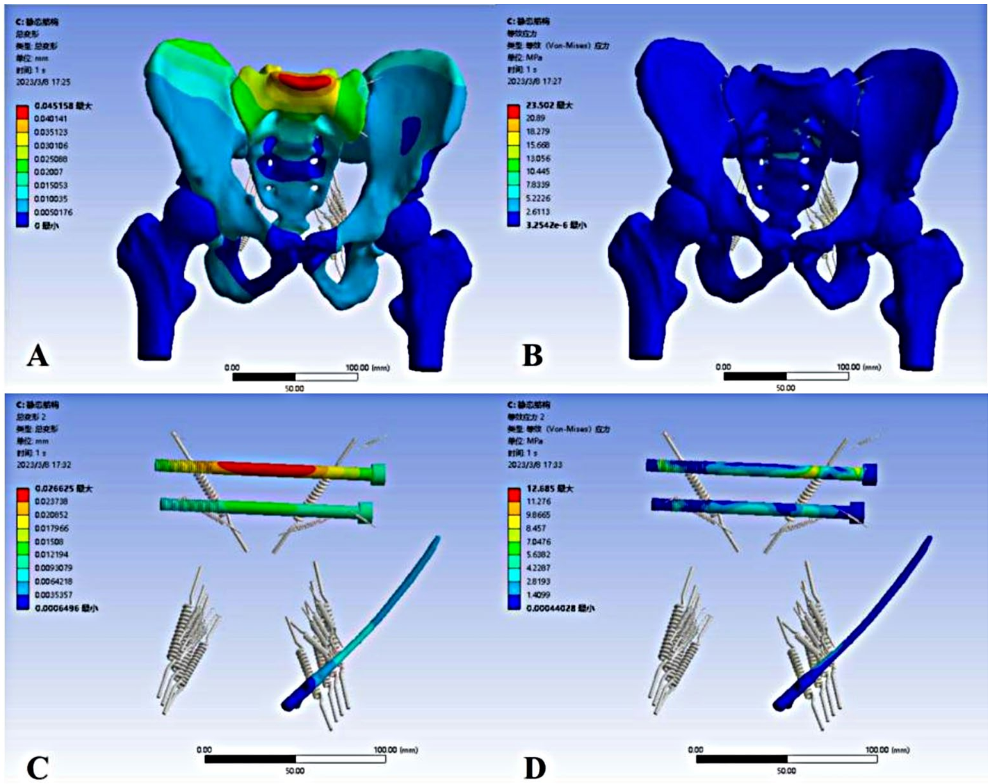

Fig. 3 The view of model 1 under vertical self-weight load: (**A**) Displacement distribution of total model. (**B**) V-M stress distribution of total model. (**C**) Displacement distribution of internal fixation. (**D**) V-M stress distribution of internal fixation

The minimum is 12.685 MPa (Fig. 3D), located in model SRSP. According to the comparison of stress cloud figure in engineering condition 1, the stress distribution of SRSP is more uniform than others groups.

Combining all groups of data (Table 5), who has the better biomechanical effect are model SRSP and model HSRP, while the worse one is model INFIX (Fig. 7).

Engineering condition 2

When simulating to face the A-P compression, it can be seen that the maximum displacement of overall model in each group, of which the highest value is 0.26266 mm, located in model SRSP. And the lowest is 0.23279 mm, located in model HSRP. Among the maximum displacement of internal fixation in each group, the highest is 0.18505 mm located in model INFIX. The lowest is 0.14732 mm, located in model HSRP. The maximum space of pubic bone broken ends is 6.4647×10^{-3}mm in model INFIX and the minimum space is 0.7488×10^{-3}mm in model (Table 4).

Among the maximum V-M stress value of overall model in each group, of which the highest is 44.334 MPa located in model INFIX. And the lowest is 29.668 MPa, located in model Plate. Among the maximum V-M stress value of internal fixation, the highest is 44.334 MPa located in model INFIX. The lowest is 18.316 MPa, located in model HSRP. According to the comparison of stress cloud figure in engineering condition 2, the stress distribution of HSRP is more uniform than others groups. (See Supplementary Figs. 1–4, Additional File 1)

Combining all groups of data(Table 5), who has the better biomechanical effect are model SRSP and model HSRP (Fig. 7).

Engineering condition 3

When simulating the force in horizontal lateral direction, it can be seen that the maximum displacement of overall model in each group, of which the highest value is 1.055 mm, located in model INFIX. And the lowest is 0.88487 mm, located in model HSRP. Among the maximum displacement of internal fixation in each group, the highest is 0.32588 mm located in model SRSP. The lowest is 0.17156 mm, located in model Plate. The maximum space of the pubic bone broken ends is 30.334×10^{-3}mm in model INFIX and the minimum space is 0.271×10^{-3}mm in model HSRP (Table 4).

Among the maximum V-M stress value of overall model in each group, of which the highest is 533.62 MPa located in model INFIX. And the lowest value is 79.129 MPa, located in model SRSP. Among the maximum V-M stress value of internal fixation, the highest is 247.68 MPa located in model INFIX. The lowest

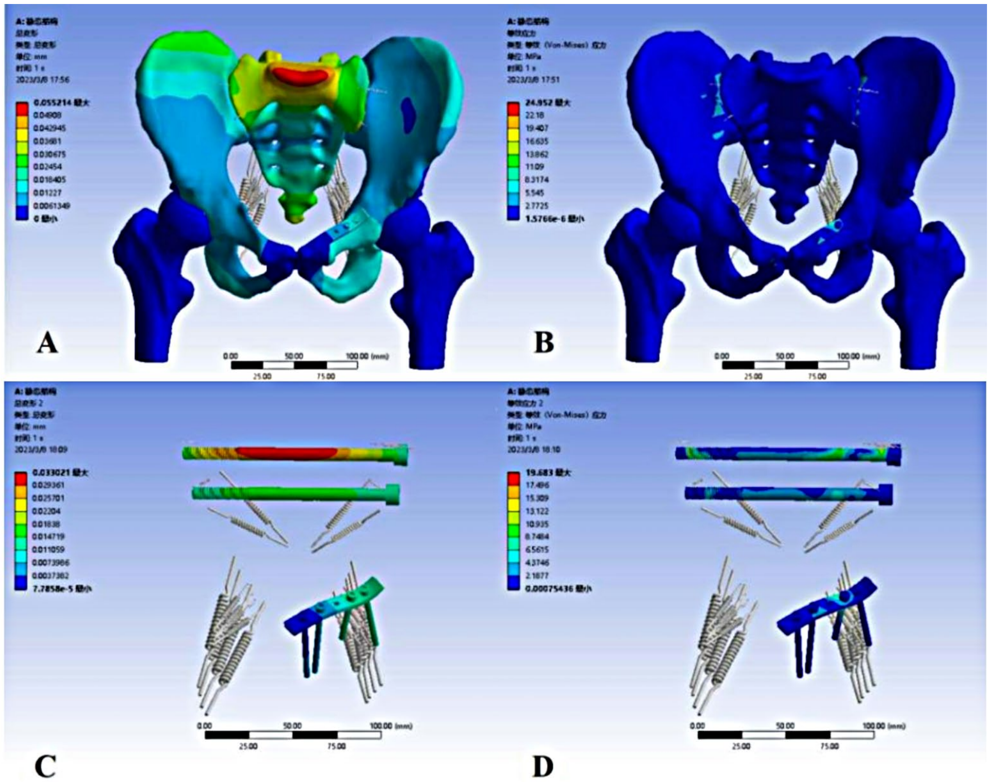

Fig. 4 The view of model 2 under vertical self-weight load: (**A**) Displacement distribution of total model. (**B**) V-M stress distribution of total model. (**C**) Displacement distribution of internal fixation. (**D**) V-M stress distribution of internal fixation

Table 4 Displacement of anterior pelvic ring fracture

Model	Engineering condition	Displacement of broken ends ($\times 10^{-3}$mm)		
		Left broken end of pubis	Right broken end of pubis	The absolute value of fracture space in horizontal direction
1	Load in vertical direction	8.0387	1.9303	2.7726
	A-P compression	121.67	124.73	0.7488
	lateral compression	48.827	36.756	0.9947
2	Load in vertical direction	15.179	2.8382	3.3153
	A-P compression	114.02	121.46	1.0742
	lateral compression	119.99	10.789	6.1931
3	Load in vertical direction	142.64	6.3706	36.8032
	A-P compression	87.527	163.75	6.4647
	lateral compression	341.55	53.636	30.334
4	Load in vertical direction	6.3726	3.77414	1.5289
	A-P compression	117.99	121.56	0.7805
	lateral compression	29.449	30.768	0.271

is 79.129 MPa, located in model SRSP. According to the comparison of stress cloud images in engineering condition 3, the stress distribution of SRSP is more uniform than others groups. (See Supplementary Figs. 5–8, Additional File 1).

Combining all groups of data (Table 4), who has the better biomechanical effect are model HSRP and model SRSP (Fig. 7).

Discussion

The pelvis is a complete ring composed of sacrum and iliums on both sides connected by strong ligaments and fibrocartilage, which plays an important role in transmitting the upper and lower stress of the axial bones. It was widely believed that injury to the posterior pelvic ring would cause significant instability of the overall pelvic ring. There is no consensus on whether simultaneous

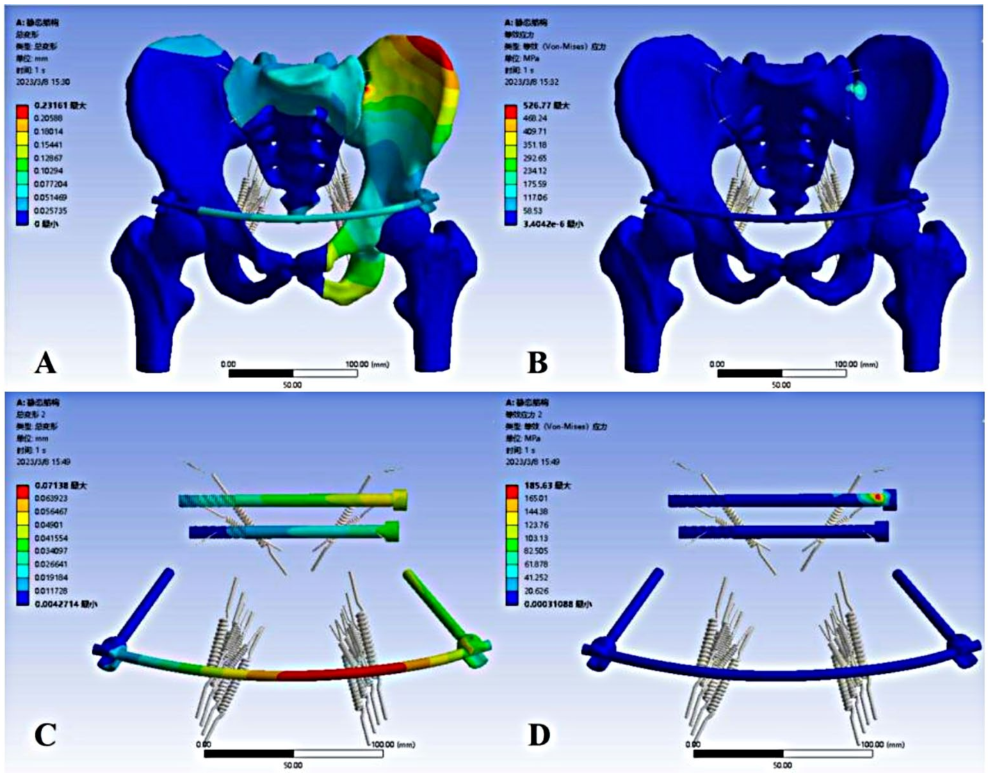

Fig. 5 The view of model 3 under vertical self-weight load: (**A**) Displacement distribution of total model. (**B**) V-M stress distribution of total model. (**C**) Displacement distribution of internal fixation. (**D**) V-M stress distribution of internal fixation

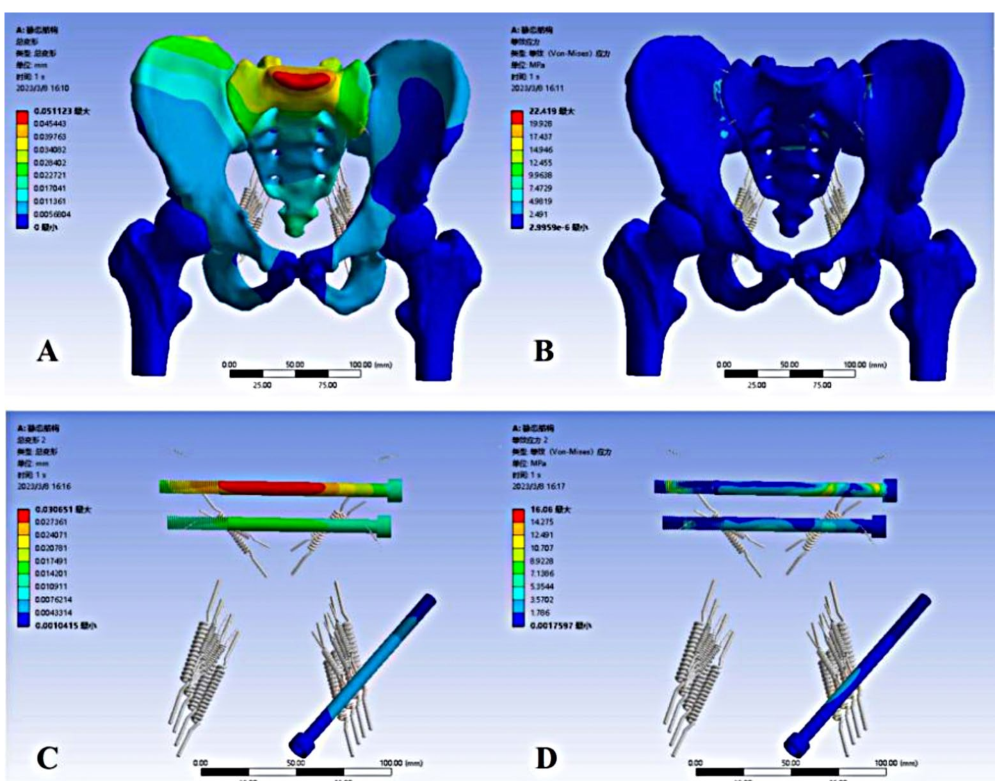

Fig. 6 The view of model 4 under vertical self-weight load: (**A**) Displacement distribution of total model. (**B**) V-M stress distribution of total model. (**C**) Displacement distribution of internal fixation. (**D**) V-M stress distribution of internal fixation

Table 5 Data of four groups of models in different conditions

Model	Engineering condition	Overall model		Internal fixation	
		Maximum displacement($\times 10^{-3}$mm)	maximum V-M stress value(MPa)	Maximum displacement($\times 10^{-3}$mm)	maximum V-M stress value(MPa)
1	Load in vertical direction	45.158	23.502	26.625	12.685
	A-P compression	262.66	38.323	151.55	21.225
	lateral compression	995.93	79.129	325.88	79.129
2	Load in vertical direction	55.214	24.952	33.021	19.683
	A-P compression	251.72	29.668	149.75	20.304
	lateral compression	947.92	86.933	171.56	86.933
3	Load in vertical direction	231.61	526.77	71.38	185.63
	A-P compression	261.93	44.334	185.05	44.334
	lateral compression	1055.0	533.62	298.42	247.68
4	Load in vertical direction	51.123	22.419	30.651	16.06
	A-P compression	232.79	43.476	147.32	18.316
	lateral compression	884.87	97.794	179.99	97.794

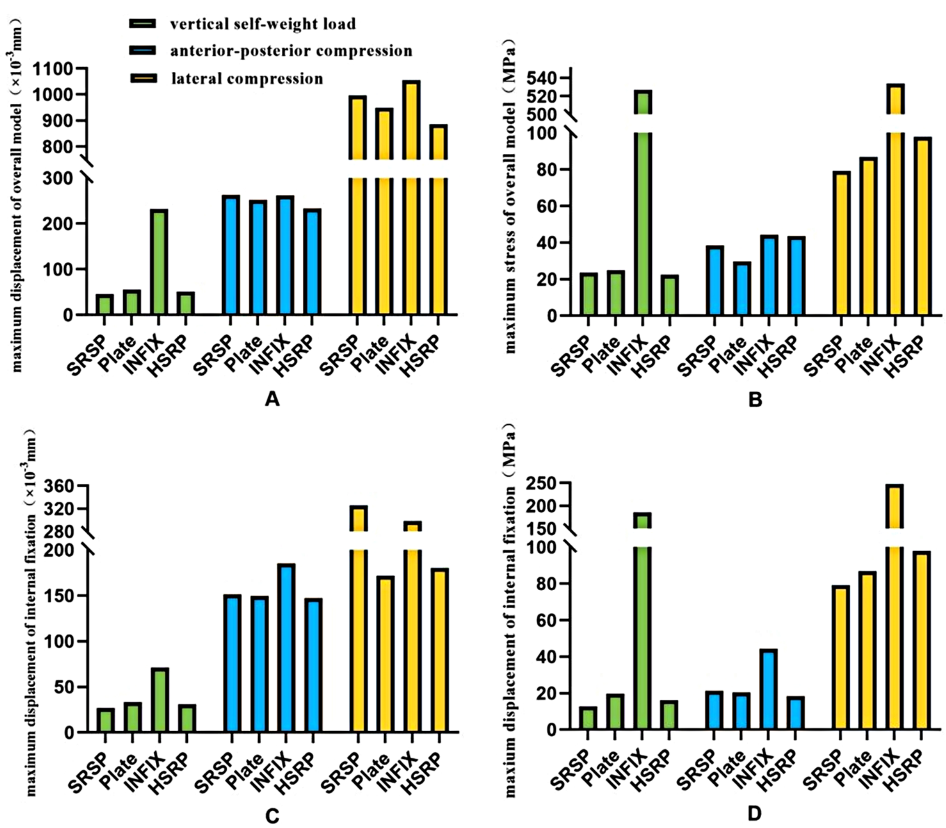

Fig. 7 The comparison of maximum stress and maximum displacement of four models under different working conditions: (**A**) The maximum displacement of overall finite element model. (**B**) The maximum stress of overall finite element model. (**C**) The maximum displacement of internal fixation. (**D**) The maximum stress of internal fixation

fixing anterior and posterior rings is as important to provide adequate stability to the pelvic ring as doing posterior rings alone [11, 12]. However, with the development of the research on anterior ring in recent years, researchers have found that the stability of anterior ring may influence the stress of posterior ring or the deformation of broken ends [13]. More attention has been paid to the reconstruction of the stability of anterior pelvic ring [14]. For the instability of the ring, restoring anatomical structure and solid fixation are the prerequisites for early functional rehabilitation, in order to meet the demands of more and more patients for a better prognosis.

It is known from the literature that the incidence of simple isolated pubic branch fractures is relatively low.

Scheyerer et al. [3]'s study showed that about 96.8% of patients with pubic branch fractures were found to be accompanied with injuries to the posterior pelvic ring. Therefore, our study chose to establish the finite element model of C1.3 fracture, which is a representative of unstable pelvic fractures. In our study, percutaneous sacroiliac screws were used to fix the posterior pelvic ring, which is a reliable and minimally invasive central fixation method, providing sufficient stability and effectively resist vertical shear and torsion forces [[15], [16]]. In this study, two sacroiliac screws were used to fix the posterior ring in all fracture models, which not only conformed to the concept of minimally invasive treatment, but also reduced the calculation error that may be caused by the unstable fixation of the posterior ring.

It is generally considered that the growth of callus is greatly affected by movement between the broken ends of fracture clinically. And it is difficult to heal when the distance between ends is more than 2 cm, which usually means the failure of internal fixation [17]. The controlled micromovements between the fracture ends can promote callus formation and fracture healing, which are important mechanical parameters in the healing process [18, 19]. Long-term follow-up by some scholars has shown that the fracture healing prognosis is better when the displacement of the broken ends of pelvic posterior ring is between 0.2 and 1 mm. Movements exceeding this range may have a negative effect on fracture healing [20–23]. In our study four groups of the maximum displacement of overall finite element model and movement of broken ends of pubis in three engineering conditions were all less than 1 mm. Under the vertical force of self-weight, the maximum displacement of overall finite element model are compared as: INFIX model > Plate model > HSRP model > SRSP model. The movement of broken ends of pubis are compared as: INFIX model > Plate model > SRSP model > HSRP model. Under the force in horizontal from forward to backward direction, the maximum displacement of overall model are compared as: SRSP model > INFIX model > Plate model > HSRP model. The movement of broken ends of pubis are compared as: INFIX model > Plate model > HSRP model > SRSP model. Under the force in horizontal lateral direction, the maximum displacement of overall model are compared as: INFIX model > SRSP model > Plate model > HSRP model. The movement of broken ends of pubis are compared as: INFIX model > Plate model > SRSP model > HSRP. Smaller displacement strain in each part of pelvis represents better biomechanical stability. In summary, it can be seen that four internal fixation schemes can effectively fix TileC1.3 pelvic fractures and provide stability. And also there was no obvious stress concentration in the four internal fixation models. Comparison between groups shows the SRSP and HSRP are superior to others.

In general, the risk of endoplant failure arises from stress load and travel distance. When there is no obvious stress concentration, the lower the maximum stress of internal fixation, the less the risk of breaking. The smaller the movement distance of internal fixation, the less the risk of loosening. Under the vertical force of self-weight, the maximum displacement of internal fixation are compared as: INFIX model > Plate model > HSRP model > SRSP model. The maximum stress of internal fixation are compared as: INFIX model > Plate model > HSRP model > SRSP model. Under the force in horizontal from forward to backward direction, the maximum displacement of internal fixation are compared as: INFIX model > SRSP model > Plate model > HSRP model. The maximum stress of internal fixation are compared as: INFIX model > SRSP model > Plate model > HSRP model. Under the force in horizontal lateral direction, the maximum displacement of internal fixation are compared as: SRSP model > INFIX model > HSRP model > Plate model. The maximum stress of internal fixation are compared as: INFIX model > HSRP model > Plate model > SRSP model. And we could discover from the stress cloud image that and the stress distribution of SRSP and HSRP were more uniform than others.

In the above engineering conditions, the maximum stress subjected to internal fixation is lower than the yield stress of titanium metal (1050Mpa), thus basically no fracture will occur [24]. In comparison, the SRSP is more advantageous in the field of less loosening.

In this study, no obvious fracture end separation, fracture or obvious deformation, or loosening of the inner plant were found in each model. And the displacement and stress changes showed similar distribution rules to the normal model, indicating that all four anterior internal fixation schemes have effectively fixed and restored the load-bearing function for TileC1.3 pelvic fractures. In addition, the data of the reconstructed plate fixation group were satisfactory in various engineering conditions, which also verified that plate internal fixation is the potential treatment standard.

Suprapubic branch hollow screw fixation is currently a commonly used method for minimally invasive treatment of pelvic fractures. However, due to the arcuated anatomy of the pubic branch, it is difficult to place nails because of the narrow bone channel in some patients, requiring multiple X-ray during operation. For some patients, the screw placement may can't be done. And nails removement may happen to middle-aged and elderly female patients with osteoporosis [25]. The SRSP was independently designed by our team based on anatomical data of the normal pelvic structure in the Chinese population (Chinese Patent No.: ZL 2020 2 1969847.8). It features a curved configuration with an approximately 15° arc, incorporating a bullet-shaped tip and an expanded cylindrical tail. (See Supplementary Figs. 9–11, Additional File 1). In contrast to the hollow screws, the arc-shaped structure of SRSP is more in line with the anatomical structure of the anterior pelvic ring. The solid bullet-shaped tip simultaneously, provides self-drilling and guidance capabilities during clinical implantation. This design facilitates reduced insertion resistance and enhanced procedural efficiency compared to traditional hollow screw systems. Combined with the uniform stress distribution and good overall control, SRSP fixation scheme can be used as a new choice for the treatment of pelvic ring injury.

This study also has limitations that should be considered. One limitation of this study is that only sketetal and ligament systems of the pelvis was employed to develop finite element models, excluding the effect muscles. Although this is a common approach in similar finite element analyses, the muscle forces which were neglected may make the stress on the broken ends more complicated. Additionally, the bone was set as an isotropic material, while bone is in fact an anisotropic material. While our fracture models cannot cover all possible real-life situations, they still offer valuable insights. Given these limitations, our conclusions would benefit from further confirmation through clinical retrospective studies and cadaveric biomechanical experiments.

Conclusion

In our study, we explored the biomechanical outcome of the new device for treating pubis rami fracture by finite element analysis. Based on the established 3D finite element model of the pelvis, four internal fixation models for TileC1.3 fractures were built and compared by biomechanical finite element analysis. With sufficient biomechanical stability, the new device SRSP can be used as a reliable fixation for the treatment of pelvic anterior ring fracture. The study provides a good theoretical basis for subsequent clinical investigations of the various therapeutic procedures in the future.

Abbreviations

SRSP	Retrograde superior ramus screw of pubis
INFIX	Minimal invasive subcutaneous internal fixator
DICOM	Digital Imaging and communications in medicine
V-M	Von Mises Stress
HSRP	Hollow screw of rami pubis
A-P	Anterior-posterior
STL	Stereo Lithography
STP	Exchange Structure of 3D Picture Files
FE	Finite element

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-05676-5.

Supplementary Material 1: Additional file: The file is PPT. The data in additional file are the results of the infite element analysis and more details about the design of SRSP. Considering the restriction of the space on printed page, we put more figures in additonal file.

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Author contributions

GM conceived and designed the study, and wrote the main manuscript. XZ, XP and ZR prepared the imaging data. WZ, XF and LY provided related guidance. YC and TZ revised the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not needed.

Consent for publication

All presentations provided consent for publication.

Competing interests

The authors declare no competing interests.

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