Anterior Stabilization in the Pubic Symphysis Separation : A Mechanical Testing

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Abstract

Four types of commonly used instruments, 1) external fixation, 2) tension wiring, 3) tension band wiring, and 4) single superior plating, for anterior stabilization of the diastasis pubic symphysis were tested for their mechanical properties under single load to failure in cadaveric pelvis by a universal testing machine. Three directions of loading, transverse tension, vertical tension and saggital compression, were used to test each type of instrumentation. Five specimens of each fixation were used for each direction of testing. The strongest instrumentation was single superior plating. Early mobilization can be advocated in the patient after fixation with this instrument. External fixation could resist transverse and saggital compression load at an acceptable level but not the vertical load. Tension band wiring could better resist vertical load than the other directions. Tension wiring was the weakest instrumentation and early ambulation should be avoided.

Key word : Pubic Symphysis Separation - Anterior Stabilization - Mechanical Testing

Separation of the pubic symphysis is one of the most common types of pelvic fracture. It is usually caused by anterior compression(1). Severe bleeding and lower urinary tract injury are commonly found in this injury which may lead to hemorrhagic shock and death of the patient. Reduction and anterior stabilization of the pubic symphysis can reduce blood loss and promote ambulation(2). There are many kinds of instrumentation which are designed and used to fix the separated pubic symphysis, such as plate and screw, special design plate, tension fixation with absorbable suture, tension wiring, tension band wiring, screw fixation, external fixation, pelvic clamp and pelvic stabilizer(3-14).

External fixation is a useful and available instrument which can be used in an emergency and in convalescent periods(2,3,6,9). Tension wiring

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and tension band wiring are commonly used to stabilize the separation of the pubic symphysis(4,12). They can be used alone or combined with external fixation and can be fixed at the end of pelvic exploration, *via* the same incision. Plate and screw fixation is also a popular instrumentation for anterior stabilization of the pelvic ring(2,3,13,14). These instrumentations are commonly used in Thailand. Our purpose was to study the mechanical properties of these devices in the cadaveric pubic symphysis of Thai patients as a guide for post operative management.

METERIAL AND METHOD

Four types of instrumentation, 1) external fixation, 2) tension wiring, 3) tension band wiring, and 4) single superior plating were used to fix the separated fresh cadaveric pubic symphysis. Then, the instrumentrated pubic symphyses were tested under single loading until failure on the universal testing machine, Shimatzu AGB 2000. The yielding load, ultimate load and stiffness of each type of instrumentation were compared.

Sixty fresh cadaveric pelvises of males in the age range of 18 to 30 years were used in the study. The size of the pubic bone, pubic symphysis, and anterior iliac crest (at the point 1 cm and 5 cm from the anterior superior iliac spine) were measured by vernier caliper, TESA, Digit-Cal 51, Switzerland, and the results were recorded. All soft tissues, femoral heads and lumbar spines were removed from the pelvis. Then, the pubic symphysis were separated by a sharp chisel. Fifteen separated pubic bones were fixed by each method of instrumentation and they were randomly chosen for each method.

In group 1, the external fixation group, 2 Shantz pins of 5 mm in diameter with 250 and 300 mm in length, were fixed on each iliac crest at a point 1 cm and 5 cm posterior to the anterior superior iliac spine respectively 50 mm in depth. The direction of the first pin 250 mm in length was pointing to acetabulum. The second pin 300 mm in length was pointing to the posterior column of the acetabulum. The AO tubular external fixation system was used to fix the 4 Shantz pins loosely together by standard clamps and tubes (Fig. 1). The clamps were fixed on the Shantz pin at a point 150 and 200 mm from the iliac crest on each side and 1 tube was used for each connection. Then, the pubic symphysis was manually compressed together *via* Shantz pins; meanwhile, all clamps of the external fixator were tightened firmly by hand.

In group 2, the tension wiring group, a coiled wire 2.0 mm in diameter and 25 cm in length was used to fix the separated pubic symphysis. The pubic symphysis was first reduced and temporarily fixed with a point reduction clamp.

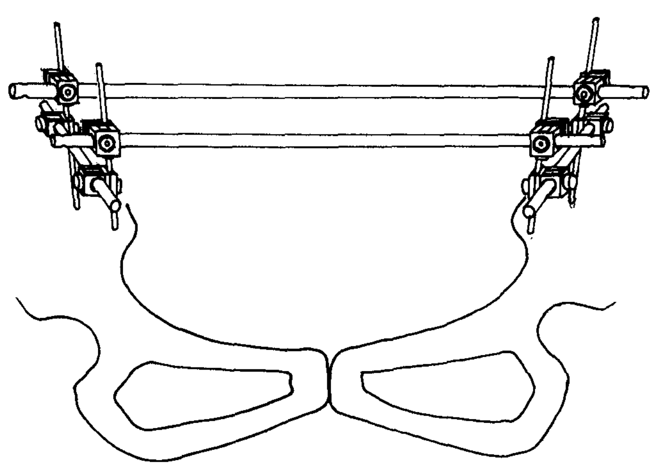

Fig. 1. External fixation for the separation of the pubic symphysis. Two 5 mm Shantz pins were used to fixed the iliac crest at 1-cm and 5-cm from the anterior superior iliac spine.

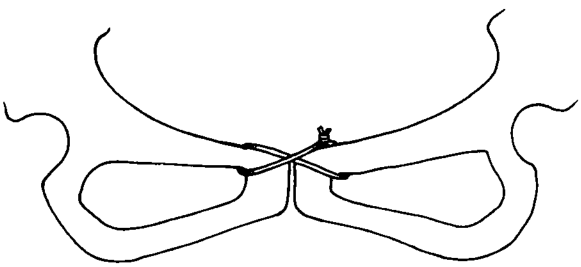

Fig. 2. **Tension wiring, 2.0 mm in diameter of coiled wire was used to fix the diastasis pubic symphysis.**

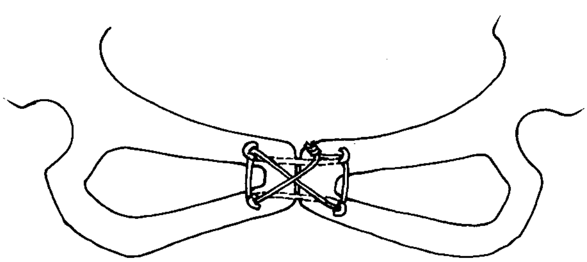

Fig. 3. **Tension band wiring, 2 Steinmann pins 4.0 mm in diameter were used to fix the symphysis in mid coronal plane and tension wiring with 2.0 mm coiled wire was used to fix in figure of 8 position beneath the Steinmann pin.**

The wire was passed into the left obturator foramen in the anteroposterior direction. The wire was curved and pulled out above the left pubic bone and passed across the anterior aspect of the symphysis to the right obturator foramen. Then, the wire was passed into the right obtulator foramen and passed anteriorly above the right pubic bone. The 2 ends of the coiled wire were twisted together at the anterior aspect of the pubic symphysis and tightened until the separated pubic symphysis was firmly closed by hand (Fig. 2).

In group 3, the tension band wiring group, 2 Steinman pins of 4 mm in diameter were used to fix the separated pubic symphysis in position. The pubic symphysis was firstly reduced and temporarily fixed with a point reduction clamp. The pins were passed into the pubic bones on each side of the symphysis in the mid coronal plane of the pubic bones. The pins were parallel to each other. The first pin lay close to the upper border of the pubic bones and the second pin lay close to the lower border of the bones. Then, a coiled wire 2.0 mm in diameter and 25 cm in length was passed under the tips of the Steinmann pins at the left pubic bone and passed across the anterior surface of the symphysis to the right pubic bone. The coiled wire was hooked beneath the tips of the Steinmann pins of the right pubic bone. Then, the 2 ends of the coiled wire were twisted together and tightened until the separated pubic symphysis was firmly closed by hand (Fig. 3).

In group 4, a 6 hole curved small reconstruction plate with 6 screws of correct length was fixed on the superior surface of the pubic bones and the superior pubic rami (Fig. 4). The plate was prebent to close the opposite gap of the symphysis. The pubic bones were reduced and temporarily fixed with a point reduction bone clamp. The screws of the middle holes on each side of the plate were fixed in ecentric position to allow maximum compression force at the symphysis pubis. Then, the other screws of correct length were fixed in neutral position.

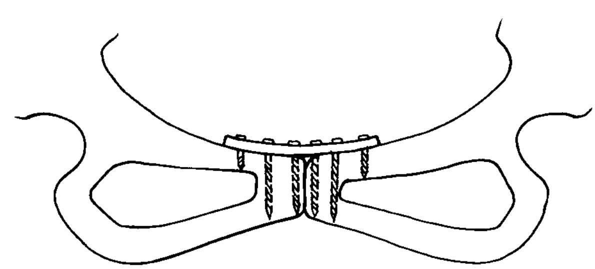

Fig. 4. **Curved 6 hole small reconstruction plate with 6 screws, 3.5 mm in diameter, was used to fix the symphysis in position.**

All of the instrumented pelvises were prepared for mechanical testing. The alar and the sacrum of every specimen were removed to open the posterior pelvic ring, so the stability of the pubic symphysis of each bone depended only on the instrumentations.

Three directions of loading were used to test each type of instrumentation. They were 1) transverse tensile loading to separate the pubic symphysis by applying a hook to each obturator foramen and pulling them apart from each other, 2) vertical tensile loading by fixing the left pubic bone to the static clamp of the universal testing machine and pulling the right pubic bone upward by a special clamp which was connected to the travelling bar of the universal testing machine, and 3) the saggital compression loading applying the compression point at the right pubic bone with the left pubic bone fixed to a special static clamp. Five specimens of each type of instrumentation were subjected to each mechanical test. All testings were operated on the same day with the same speed of 10 cm per min at 25°C and 65 per cent relative humidity. The loading was stopped when metal to bone or metal to metal failure occurred. The yielding load, the ultimate load and the stiffness of each instrumentation were recorded and compared.

RESULTS

The average size of all specimens in each group were comparable (Table 1).

In group 4, where plate and screws were used to fix the pubic symphysis, the yielding load, ultimate load and stiffness were significantly higher than the others in all directions (Table 2, 3, 4). The standard deviations of every measurement in all specimens were also the lowest. Group 1, the external fixation group, had a rather high yielding load, ultimate load and stiffness in transverse and saggital loading; however, these mechanical properties were rather low under vertical tensile loading (Table 2, 3, 4). On the other hand, in group 3, the tension band wiring group, the tested specimens could better tolerate vertical tensile loading than transverse and saggital loading (Table 2 and 3). Group 3 was the weakest in terms of mechanical properties in all directions (Table 2, 3, 4).

DISCUSSION

Pubic symphysis is an important structure which connects the 2 innoninate bones on the anterior aspect of the pelvic ring. The size of the Thai pelvis is rather small compared to Caucasians. The average width of the pubic bone in the anteroposterior dimension is 13.05±2.44 mm which might not be suitable for 4.5 or 6.5 mm screw fixation. These large screws are preferred with a specially designed plate by some authors(10,11,14). In external fixation of the pelvis, most authors prefer to use 3 Shantz pin(15,16). However, as the iliac crest of an average Thai is rather small, only 2 Shantz pins of only 5 mm in diameter are usually used. From our data the average width of the iliac crest at 1 cm and 5 cm from the anterior superior iliac spine which is the most suitable site for fixation was 13.68±1.51 mm and 15.61±0.81 mm respectively. So, in our study, 3.5 mm screws with a curved small reconstruction plate were chosen in group 4 and only 2 Shantz pins on each iliac crest were used in group 1.

Plate and screws could resist vertical force at certain levels better than the other types of fixation. So, this procedure is useful in severe unstable pelvic fractures which have an associated posterior ring fracture. The techniques of plate and screw fixation were also unique as the standard deviation of every test in our study was small. That meant this fixation had high accuracy and repeatability.

External fixation was second in strength and stiffness. It is a rather technical demanding procedure as there is no adequate guiding instrument. The fixation point is also far away from the injured area, resulting in less strength and stiffness, especially under vertical tensile loading.

Tension band wiring was the third type used in this study. It could tolerate vertical tensile loading better than the external fixation. Although it has been designed to withstand tension, the main structure subject to deforming force is the coiled wire. As the 2 Steinmann pins were fixed in a parallel position, they gave little resistance to the transverse tensile load. On the other hand, these 2 Steinmann pins could resist the vertical tensile load while the coiled wire gave very low resistance to the load in this direction. Tension wiring with only coiled wire gave the poorest mechanical properties.

Meissrer et al studied the physiologic load which could produce mean movement of the pubic symphysis. They concluded that for mobilization of the patients with a symphysial rupture on partial weight bearing, neutralization of the mean acting force during one-leg stance of 169 N in the vertical direction and 68 N in the saggital direction must

Table 1. The dimensions of the pubic bone, pubic symphysis and the anterior iliac crest of the fresh cadaveric bone of each method of instrumentation.

Dimentions of pubic symphysis (mm)	A-P width at mid pubic bones		Superoinferior width at mid pubic bones		The width of pubic bones and the symphysis in coronal plan	Thickness of anterior iliac crest			
						at 1 cm		at 5 cm	
Method of instrumentation	Right	Left	Right	Left		Right	Left	Right	Left
Group 1 (External fixation)									
: average	13.20±2.43	12.73±1.66	43.26±2.7	43.83±3.48	52.36±7.06	13.57±1.49	13.73±0.56	16.32±0.05	14.31±1.50
: range	10.60-15.42	11.20-14.52	40.4-45.9	39.82-48.10	44.19-62.11	12.45-15.23	13.14-14.25	16.30-16.35	14.60-14.80
Group 2 (Tension wiring)									
: average	13.31±2.30	12.20±1.70	43.50±2.60	43.63±3.51	52.51±8.11	13.72±1.6	13.61±0.49	16.41±0.091	14.69±1.30
: range	10.50-15.80	11.25-14.90	40.1-46.1	39.1-47.9	42.9-61.8	12.51-15.52	13.08-14.11	6.41-16.42	14.59-14.76
Group 3 (Tension band wiring)									
: average	13.26±2.50	12.89±1.66	43.40±2.9	43.90±3.71	52.41±7.24	13.54±1.51	13.71±0.51	16.30±0.07	14.69±1.40
: range	10.50-15.90	11.35-14.58	39.9-45.9	39.90-48.20	44.15-62.31	12.41-15.25	13.12-14.20	16.29-16.34	14.61-14.79
Group 4 (Single plating)									
: average	13.34±2.41	12.72±1.64	43.30±2.7	43.70±3.61	52.39±7.00	13.56±1.50	13.75±0.61	16.27±0.04	14.70±1.49
: range	10.61-15.39	11.27-14.53	40.2-46.3	39.00-47.00	44.20-62.10	12.43-15.30	13.13-14.30	16.20-16.30	14.61-14.79

Table 2. The results of mechanical testing of the instrumented pubic symphysis under transverse tensile loading.

Result of testing Groups	Yielding load (N)	Ultimate load (N)	Stiffness (N/mm)	Sites of failure	P-value
Group 1	320.1±21.8	371.4±29.4	38.4±9.4	Shantz pins to bone interface	
Group 2	31.4±8.6	34.1±9.1	4.4±2.9	Coiled wire	P<0.001
Group 3	114.4±17.9	120.9±18.3	22.9±8.4	Coiled wire, Steinmann pin and bone interface	
Group 4	368.1±6.9	401.3±7.6	73.6±10.4	Screws and bone interface	

Table 3. The results of mechanical testing of the instrumented pubic symphysis under vertical tensile loading.

Result of testing Groups	Yielding load (N)	Ultimate load (N)	Stiffness (N/mm)	Sites of failure	P-value
Group 1	163.8±16.1	197.2±20.0	16.4±3.1	Shantz pins and bone interface	
Group 2	15.9±5.2	19.1±6.1	3.2±1.1	Coiled wire	P<0.001
Group 3	237.8±14.6	259.1±18.6	5.89±16.1	Steinmann pin, coild wire	
Group 4	331.1±6.0	352.9±7.1	65.4±8.1	Screws and bone interface	

Table 4. The results of mechanical testing of the instrumented pubic symphysis under saggital tensile loading.

Result of testing Groups	Yielding load (N)	Ultimate load (N)	Stiffness (N/mm)	Sites of failure	P-value
Group 1	368.9±14.3	399.9±15.1	74.1±9.4	Shantz pins and bone interface	
Group 2	23.4±6.1	25.0±71	2.61±1.9	Coiled wire	P<0.001
Group 3	142.2±15.9	156.8±14.4	29.5±10.0	Steinmann pins	
Group 4	449.4±7.1	480.1±9.1	90.1±11.4	Screws and bone interface	

be achieved by an adequate fixation device(17). From our data, group 3 and 4 could withstand the recommended load. External fixation had low yielding load in the vertical direction which might not be strong enough for the deforming force. However, in the saggital and transverse direction, external fixation could resist rather a high load. With regard to cost benefit, tension band wiring might be the best in anterior stabilization of the pubic symphysis separation as it could withstand rather high loading while it was a simple instrumentation.

On clinical points, early mobilization may be advocated in the pubic symphysis separation patients who have been fixed with plate and screws. In the patients who were treated with tension band wiring or external fixation for the diastasis pubic symphysis, a slight delay in ambulation and using walking aids is recommended. If only tension wiring was used to treat diastasis pubic symphysis, prolonged bed rest should be advised.

SUMMARY

The strength and stiffness of external fixation, tension wiring, tension band wiring, and plating for separated pubic symphysis of the fresh cadaveric pelvic bones were tested under transverse, vertical and saggital loading until failure on the universal testing machine. Single loading with a speed of 10 mm/min at 25°C and 65 per cent rela-

tive humidity was used in this study. Five specimens from each type of fixation were subjected to each type of loading. Plate and screw fixation had the highest strength and stiffness followed by external fixation and tension band wiring. Simple wiring could not prevent vertical and saggital loading.

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REFERENCES

1. Gamble JG, Simmons SC, Freedman M. The symphysis pubis. Anatomy and pathologic considerations. Clin Orthop 1986;203:261-72.
2. Matta JM. Indication for anterior fixation of pelvic fractures. Clin Orthop 1996;329:88-96.
3. Chevalley F, Husmann O, Genton A, Blanc CH. External fixator in severe traumatic injuries of the pelvis: results apropos of 20 consecutive causes. Swiss Surg 1996;2:62-6.
4. Decker R, Ruf W. Tension fixation of rupture of the symphysis with woven polydioxanone sutures. Zeitschrift Orthopaedic Ihre Grenzgebiete 1988; 126:14-8.
5. Ganz R, Krushell RJ, Jakob RP, Kuffer J. The antishock pelvic clamp. Clin Orthop 1991;267: 71-8.
6. Ghanayen AJ, Stover MD, Goldstein JA, Bellon E, Wilber JH. Emergent treatment of pelvic fractures. Comparison of method for stabilization. Clin Orthop 1995;318:75-80.
7. Heini PF, Witt J, Ganz R. The pelvic C-clamp for the emergency treatment of unstable pelvic ring injuries. A report on clinical experience of 30 cases. Injury 1996;27(Suppl-1):38-45.
8. Routt ML Jr, Simonian PT, Grujic L. The retrograde medullary superior pubic rami screw for ring disruption: a new technique. J Orthop Trauma 1995;9:35-44.
9. Simonian PT, Routt ML Jr, Harrington RM, Mayo KA, Tencer AF. Biomechanical stimulation of the anterior compression injury of the pelvis. An understanding of instability and fixation. Clin Orthop 1994;309:245-56.
10. Simonian PT, Routt ML Jr, Harrington RM, Tencer AF. Box plate fixation of the symphysis pubis: biomechanical evaluation of a new technique. J Orthop Trauma 1994;8:483-9.
11. Simonian PT, Schwappach JR, Routt ML Jr, Agnew SG, Harrington RM, Tencer AF. Evaluation of new plate designs for symphysis pubis internal fixation. J Trauma 1996;41:498-50.
12. Staurt PR, Talbot D, Milne DD. Internal fixation of pubic diastasis with a tension banding technique. Injury 1990;21:223-4.
13. Varga E, Hearn T, Powell J, Tile M. Effects of method of internal fixation of symphyseal disruptions on stability of the pelvic ring. Injury 1995;26: 75-80.
14. Webb LX, Gristina AG, Wilson JR, Rhyne AL, Meredith JH, Hansen ST Jr. Two-hole plate fixation for traumatic symphysis pubis diastasis. J Trauma 1988;28:813-7.
15. Burgess AR, Jones AL. Fractures of the pelvic ring. In : Rockwood CA Jr, Green DP, Bucholz RW, Heckman JD, eds. Fractures in adults, Vol 2, 4th ed. Philadelphia: Lippincott-Raven, 1996:1605-10.
16. Russell TA. Fractures of hip and pelvis. In : Crenshaw AH, Daugherty K, Curro C, eds. Campbell's Operative Orthopaedics, Vol 2, 8th ed. St Louis: Mosby, 1992:895-988.
17. Meissrer A, Fell M, Wilk R, Boenick U, Rahmanzadeh R. Biomechanics of the pubic symphysis. Which forces lead to mobility of the symphysis in physiological conditions? Unfallchirurg 1996;99: 415-21.

เปรียบเทียบคุณสมบัติทางกลศาสตร์ของการยึดตรึงกระดูกหัวหน่าวจากด้านหน้าเพื่อรักษาการแยกตัวของกระดูกหัวหน่าว

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รายงานผลการศึกษาความแข็งแรงของการยึดตรึงกระดูกหัวหน่าวทางด้านหน้าด้วย 4 วิธีการ 1) การใช้อุปกรณ์ยึดตรึงจากภายนอก 2) การใช้ลวดมัด 3) การใช้ลวดมัดร่วมกับลวดแท่งแทงผ่านกระดูกหัวหน่าว และ 4) การใช้แผ่นดามกระดูกและสกรู ศึกษาในกระดูกหัวหน่าวของศพและนำมาทดสอบโดยใช้เครื่องทดสอบคุณสมบัติทางกายภาพ แรงกระทำมี 3 ทิศทางคือ 1) ในแนวดึงกระดูกหัวหน่าวแยกจากกันในแนวราบ 2) ในแนวดิ่ง และ 3) แรงกดจากด้านหน้า โดยใช้เครื่องทดสอบดึงจนการยึดตรึงหลุดจากกันในครั้งเดียว ผลการทดสอบพบว่า การยึดตรึงกระดูกหัวหน่าวด้วยแผ่นดามกระดูกและตะปูควงแข็งแรงที่สุด ในทางคลินิกสามารถให้ผู้ป่วยเคลื่อนที่ได้เร็ว การใช้อุปกรณ์การยึดตรึงจากภายนอกทนต่อแรงกระทำในแนวดิ่งได้ไม่ดี การใช้ลวดมัดร่วมกับลวดแท่งผ่านกระดูกหัวหน่าว ทนต่อแรงดึงแยกในแนวราบไม่ได้ดี ส่วนการใช้ลวดมัดอ่อนแอที่สุด การเคลื่อนย้ายผู้ป่วยหลังผ่าตัดต้องให้ความระมัดระวังเป็นพิเศษ

คำสำคัญ : การแยกตัวของกระดูกหัวหน่าว – การยึดตรึงจากด้านหน้า – เปรียบเทียบคุณสมบัติทางกลศาสตร์

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