CORRELATION BETWEEN SYMPHESIS PUBIS' OPENING AND SIJ's OPENING DURING OPEN BOOK INJURY

Nabil Ebraheim*, Mohamed Samir Hefzy, Hongsheng Lin, Anis Mekhail*, Richard Yeasting****

Biomechanics Laboratory, Department of Mechanical, Industrial and Manufacturing Engineering
The University of Toledo, Toledo Ohio 43606

Dept. of Orthopaedic Surgery* and Department of Anatomy**, The Medical College of Ohio, Toledo, Ohio 43699

Dept. of Orthopaedic Surgery***, University of Illinois at Chicago, Chicago, Illinois 60612

ABSTRACT

The objective of this study is to determine the three dimensional kinematics of the human pelvis including both sacroiliac joints (SIJ's) following a simulated open book fracture. Data were obtained from tests performed on cadavers where fracture was induced by applying anterior-posterior compressive loads to the pelvis. An electromagnetic digitizing and motion tracking system was utilized to measure the morphology of the pelvis and its motion during the simulated open book fracture.

The results obtained from this study indicate that there is a direct positive correlation between the opening of the symphesis pubis and the opening of the SIJ during open book injury. The results also indicate that the pubic bone on the side of the injury displaces inferiorly on the outlet x-rays.

INTRODUCTION

Three major classifications for pelvic ring disruptions have been developed and utilized by orthopedic surgeons in assessing patients. The first classification is based on the site of injury and was developed by Letournel and Judet [1]. The second classification is based on the mechanism of injury and was developed by Young and Burgess [2]. The third classification combines both mechanism of injury and stability and was developed by Tile [3]. In the Young and Burgess [2] classification, three modes of failure are identified: anteroposterior compression injury, lateral compression injuries and vertical shear injury. Young and Burgess' three-pattern classification has the advantage of alerting the surgeon to potential resuscitation problems associated with pelvic fractures and allowing appropriate surgical decisions. However, the mechanics of each of these three types of injury is not fully understood.

Anteroposterior pelvic injuries usually involve pedestrians and motorcyclists as well as victims of Motor Vehicle Accidents (MVA). This work focuses specifically on open book injury of the pelvis, a common anteroposterior injury, which is often encountered in MVA. This particular injury occurs at different progressive steps. At the time of the insult, anterior-posterior (A/P) force is inflicted on the pelvis. This force causes an initial failure of the symphysis pubis or an initial fracture to the pubic bone. This allows the anterior portion of the pelvic ring to be separated apart. As the A/P force increases, this separation increases causing rupture first to the anterior sacro-iliac ligament followed by failure of the posterior sacroiliac ligament; both ligaments being posteriorly located in the pelvic ring. A complete failure of the pelvic ring occurs when both sacro-iliac ligaments rupture. The specific aim of this project is to simulate open book fracture in a laboratory environment in order to better understand the mechanics of this injury.

METHODS

Fresh frozen cadaver pelvi were used in this study. Each specimen was allowed to thaw at room temperature 24 hours before testing. Careful dissection was conducted in order to isolate the pelvic ring and to remove all excessive muscles beyond the L5 level while keeping intact the ligamentous structures that provide stability to the pelvic ring. An electromagnetic motion tracking system, namely the 3-Space [4], was used to measure the relative positions and orientations of the sacrum, right and left ilia. The system includes a source and several sensors. Each specimen was instrumented by rigidly attaching the source to the left ilium, one sensor to the anterior surface of the sacrum and another sensor to the right ilium. The symphesis pubis was then sharply disrupted. In order to simulate anteroposterior compression of the pelvis, it was positioned prone in an 1122 Instron Machine resting on four points: the two pubic tubercles and the two anterior superior iliac spine (ASIS).

Loading was then applied in a direction perpendicular to the plane containing these four points which lay in a plane parallel to the frontal plane. A 36 cm x 36 cm x 18 mm thick piece of plywood was attached to the moving head of the Instron to facilitate the application of the compressive load to the sacrum. Also, in order to eliminate friction from the surface where the pelvis is resting anteriorly, plastic sheets soaked with liquid soap were placed between the pelvis and the fixed base of the Instron. This allowed the symphesis pubis and the sacroiliac joints to open freely under compressive loads.

During testing, the load was increased incrementally until the ischial tuberosities were subjected to direct loading. At this position, testing was stopped because loading was not applied to the sacrum. At this stage, it was observed in both specimens that the left SIJ was completely disrupted while the right SIJ was opened partially. The specimen was then unloaded, removed from the Instron, and the right SIJ was manually failed. Three tests were then conducted. The first test simulates only opening of the left SIJ. The pelvis was thus held such that both right and left SIJ's were closed, then manual external rotation was applied to the left SIJ while holding the pelvis in a supine position. The output of the 3-SPACE system was collected for different openings of the symphesis pubis until maximum opening. The second test was conducted to simulate only opening of the right SIJ by manually externally rotating the right SIJ. The third test was conducted by applying manually equal external rotations to both joints until maximum opening, simulating thus their simultaneous openings.

Motion data consisted of the spatial position and orientation of the axes located in each of the two sensors attached to the sacrum and the right ilium, respectively, with respect to the coordinate system of axes located in the source which was attached to the left ilium, at different positions of the pelvic ring. The SIJ's were disarticulated after all motion data were collected. Care was taken in order not to alter the position of the source and the sensors. In order to establish the global coordinate system of axes on the sacrum, the following landmarks were then digitized: the middle of the promontory, the right and left anterior superior iliac spines, and the right and left pubic tuberosities.

Using the digitization data, the sacrum (global) coordinate system of axis was determined and the transformations between the source and/or each sensor and the sacrum bony system were calculated. Combining these transformations with the motion data, the relative positions between the right ilium, the left ilium and the sacrum were determined at different stages of a simulated open book fracture.

RESULTS

Results were obtained from two (2) cadaver pelvic specimens. Specimen 1 was obtained from a male donor while specimen 2 was obtained from a female donor. At each position of the pelvis during each of the three simulations, the right and left sacroiliac joint openings, and the symphysis pubis opening were calculated. Figure 1 shows the correlation between SIJ opening and symphysis pubis opening for specimen # 1 when only the right SIJ was opened: as the symphysis pubis opening increased, the joint opening increased. Similar results were obtained for specimen # 2, and for the other two testing conditions.

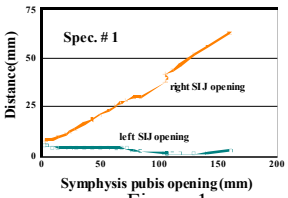

Figure 1

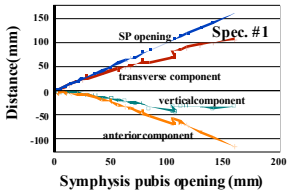

Figure 2

The variations in the transverse, vertical and anterior components of the symphysis pubis opening vector were also calculated. These three quantities represent the components of the position vector of the right symphysis pubis with respect to the left symphysis pubis as origin. The results show that when only the right SIJ was opened while the left SIJ was kept closed, the right pubic bone moved posterior and inferior to the left pubic bone; these results are shown in Figure 2. This trend was reversed when only the left SIJ was opened and the right SIJ was kept closed; the symphysis pubis opening vector was found to have anterior and superior components at all joint positions. This indicates that the left pubic bone moved posterior and inferior to the right pubic bone. When both SIJ joints were opened simultaneously, the symphysis pubis opening did not have a vertical component. Also, the anterior component was negligible up to 100 mm of symphysis pubis opening. This was expected since a symmetric motion occurred when both joints were opened simultaneously. For larger symphysis pubis openings, a small anterior component was identified, but most of the opening was in the transverse direction.

DISCUSSION

The results obtained from this study indicate that there is a direct positive correlation between the opening of the symphysis pubis and the opening of the SIJ during open book injury. Theoretically, one may thus conclude that the extent of injury of the SIJ can be estimated from the degree of opening of the symphysis pubis as demonstrated on anteroposterior x-rays. However, due to the recoil of the pelvis after sustaining the injury, the degree of the SIJ injury will be underestimated.

The results obtained from this study also show that in open book pelvic injuries, the pubic bone on the side of injury displaces inferiorly on the outlet x-rays. This is important since the initial assessment of the open book injury in the emergency room includes outlet projection x-rays. From this study, the vertical displacements of the pubic bones on these x-rays can help the orthopedic surgeon in differentiating this type of injury from vertical shear injuries. In open book pelvic injury, the pubic bone on the side of injury will displace inferiorly, in contrast to the superior displacement that occurs in vertical shear injuries.

REFERENCES

1. Judet, et al., J. Bone and Joint Surgery, 46A:1615, 1964.
2. Young, J.W.R. and Burgess, A.R., "Radiological Management of Pelvic Ring Fractures", Baltimore, Urban & Schwarzenberg, 1987.
3. Tile, Marvine, "Fractures of the Pelvis and Acetabulum", Williams and Wilkins, 2nd edition, 1995.
4. Hefzy, et al., JBE., Vol. 14, July 1992, pp. 329-343.