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EFFECTS OF SALTER PELVIC OSTEOTOMY ANGLE ON CONTACT AREA AND PRESSURE DISTRIBUTION IN THE HIP JOINT: AN EXPERIMENTAL STUDY

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Abstract

The hip dysplasia is described by an irregular relation between the femoral head and the acetabulum. Insufficient coverage of the femoral head by the acetabulum leads the development of dysplasia in the incongruity hip joint. Several osteotomies are carried out for treatment by changing with coverage angle of the femoral head in the hip joint. In this paper, the effects of osteotomy techniques used in the surgery applications on the coverage angle are investigated experimentally. Salter osteotomy technique was applied on a patient-specific artificial hip models manufactured at different osteotomy angles. The contact pressure distribution and area were measured by using Fuji Film Prescale sensor in the hip joint. The results were compared with each other. The average contact pressure expectedly decreases as long as osteotomy coverage angle increases but, the contact area decreases unexpectedly.

SALTER PELVİK OSTEOTOMİ AÇISININ KALÇA EKLEMİNDE TEMAS ALANINA VE BASINÇ DAĞILIMINA ETKİLERİ: DENEYSEL ÇALIŞMA

Anahtar Kelimeler
Salter Osteotomy
Hip Dysplasia
Contact Stress
Contact Area
Coverage Angle
Biomechanics

Özet

Kalça displazisi femur başı ve asetabulum arasındaki uyumsuzluk olarak tanımlanır. Asetabulum tarafından femur başının yetersiz örtünmesi uyumsuz kalça eklemlerinde displazi oluşumuna yol açar. Kalça ekleminde tedavi amaçlı femur başının örtünme açısının değiştirilmesi ile çeşitli ostetotomiler gerçekleştirilmektedir. Bu çalışmada örtünme açısı üzerine cerrahi uygulamalarda kullanılan osteotomi tekniklerinin etkileri deneysel olarak incelendi. Farklı osteotomi açılarında yapay olarak üretilen hastaya özgü kalçada Salter osteotomi tekniği uygulandı. Kalça ekleminde Fuji Film sensör kullanılarak temas basınç dağılımı ve alanı hesaplandı. Sonuçlar kendi arasında kıyaslandı. Osteotomi örtünme açısı arttıkça ortalama temas basıncı beklendiği gibi azalırken temas alanı beklenmedik şekilde azaldı.

1. Introduction

The hip dysplasia is described by an irregular relation between the femoral head and the acetabulum. Insufficient coverage of the femoral head by the acetabulum leads the development of dysplasia in the incongruity hip joint. This causes increased force and abnormal wear on the cartilage and labrum. The stresses and pressure distributions usually change with coverage angle of the femoral head in the articular surface of hip joint (Mavcic et al., 2002; Iglic et al., 2002; Tsumura et al.,2005). Pelvic osteotomy is often preferred as surgeries for treatment of hip dysplasia by re-orienting the acetabulum (Tsumura et al., 2005; Karami et al. 2010; Böhm et al. 2002). Acetabular osteotomies aim to increase the contact area, reduce the contact stresses and normalize the weight-bearing forces whereby is to establish normal biomechanical forces around the hip joint (Tsumura et al., 2005; Hipp et al., 1999).

Acetabular osteotomies are performed to change the shape of the hip joint involve re-shaping the shallow hip socket. The acetabulum are split from pelvis and rotated to lateral and anterior side. In this way, the acetabulum can be redirected to cover the anterolateral deficiency. The rotating angle exactly what needs to be corrected in acetabulum osteotomy is decided by the surgeons using X-ray, CT or an arthrogram (Sen et al., 1996). The success of

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determined angle action depends on the shape of the socket and the surgeon's experience (Sen, 2008). The decrease in stress and increase in contact area is a direct result of a significant increase in the angle osteotomy. Hence, the level of the angle in osteotomy plays a significant role in treatment process.

In this study, contact pressure and area of the hip joint were measured experimentally using the artificial model of a dysplastic hip in different Salter osteotomy angle. The effects of the angle in stress distribution were evaluated after acetabular osteotomy.

2. Material and Methods

The dysplastic hip joint of the left side of patient was modeled in three dimensional form using the computerized tomography (CT) images obtained in vivo of a adult female patient. The components of the dysplastic hip joint including pelvis, proximal femur, articular cartilages of both femur head and acetabulum were modeled in STL data format and manufactured using their 3D computer aided design (CAD) models. The biomodel of the pelvis, femur, femur cartilage and acetabulum were manufactured with plaster-like powder, aluminum alloy (Al-5083), RTV silicone and Hot melt glue stick material, respectively. The details of methods produced have been reported in previous study (Mutlu et al., 2014).

Different special equipments were designed and produced to hold the artificial dysplastic hip joint on the workbench of the press in a position of regular standing (vertical) posture. A suitable special jig was designed and manufactured to hold the pelvis model on the workbench of the hydraulic press. The pelvis was fixed to press and later Salter osteotomy was performed according to surgery procedure. Firstly the cutting line was marked with a pencil (Figure 1a). The osteotomy angle was arranged in lateral and anterior direction using rotational clamp (Figure 1b). The lower part of pelvis was clamped using specific apparatus (Figure 1c). The pelvis was cut with handsaw over the osteotomy line (Figure 1d). The pelvis and femur were positioned to initial stance again (Figure 1d). The edges of two cut part were butted as seen in Figure (Figure 1e). Finally two parts were mounted using screws according to Salter pelvic osteotomy (Figure 1f).

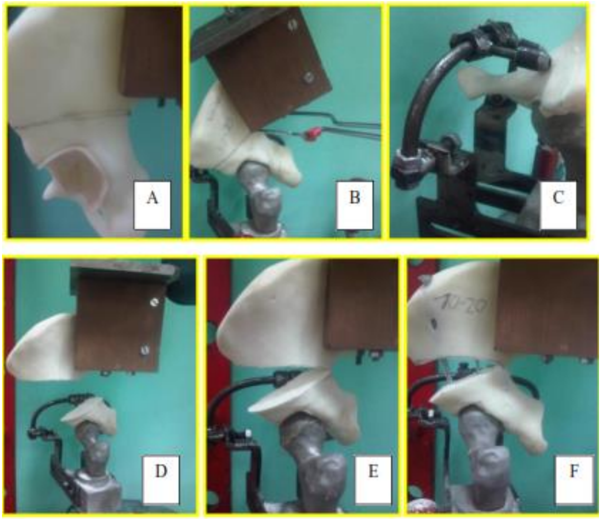

Figure 1 Salter osteotomy on artificial dysplastic hip joint

A load cell having a ton capacity was attached between the press base-plate and the femur. Pressure sensitive film (Fuji Photo Film Co., Ltd., Japan) is prepared in rosette form and sealed using strech film and inserted on the artificial cartilage of the femur head. The pressure sensitive films were used to measure the contact pressures by compressing between the articular cartilages of both femur head and pelvis acetabulum. A compression force of 80±2 kgf with a pressure sensitive film loading rate procedure was applied considering single leg stance in the tests (Fig2).

Figure 2 Test rig

The calibration of the film before using in the tests was performed considering the widely used technique (Liggins et al., 1992). The details of the calibration have been reported in previous study (Mutlu et al., 2014). After applied force, the films with colored red stains were scanned and the pressure and contact area measurement was calculated with colored stains according to calibration curve obtained from calibration tests using MATLAB software.

3. Results

In order to evaluate the contact pressure distributions of a dysplastic hip joint, the scanned images of the pressure films with the colored stains were used to calculate the pressure values employing the MATLAB program as seen in Fig. 3. The contact areas and average contact pressure values of the artificial dysplastic hip joint used in this study were measured in different osteotomy angle. The result was given in Fig 4 and 5. The results of previous study were added to the graph in order to compare the results. The results were compared both previous study and each other

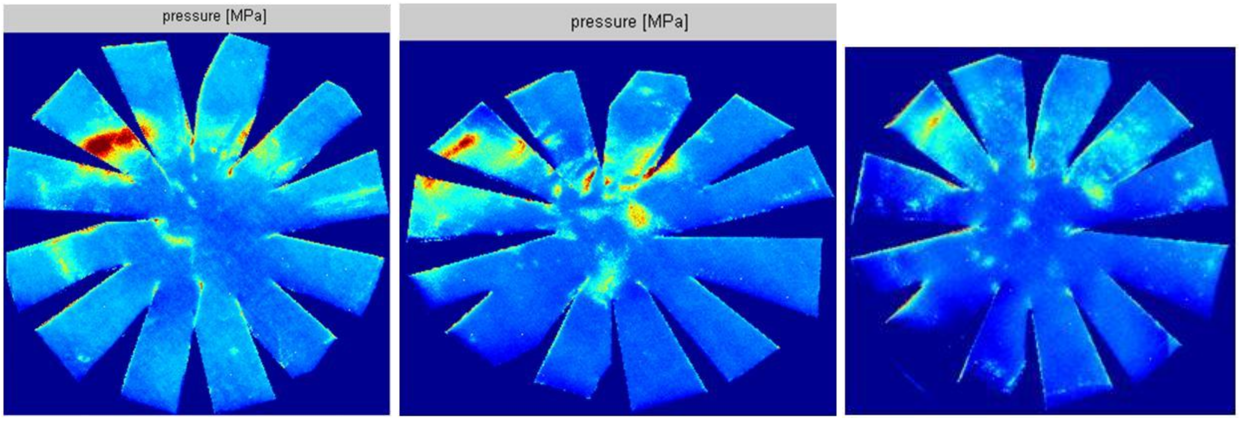

Figure 3 The pressure distributions of the 10°-10°, 20°-20° and 30°-30° angle level (from left to right, respectively) on the pressure sensitive films (The top and left of the film is positioned to femur superior and posterior, respectively)

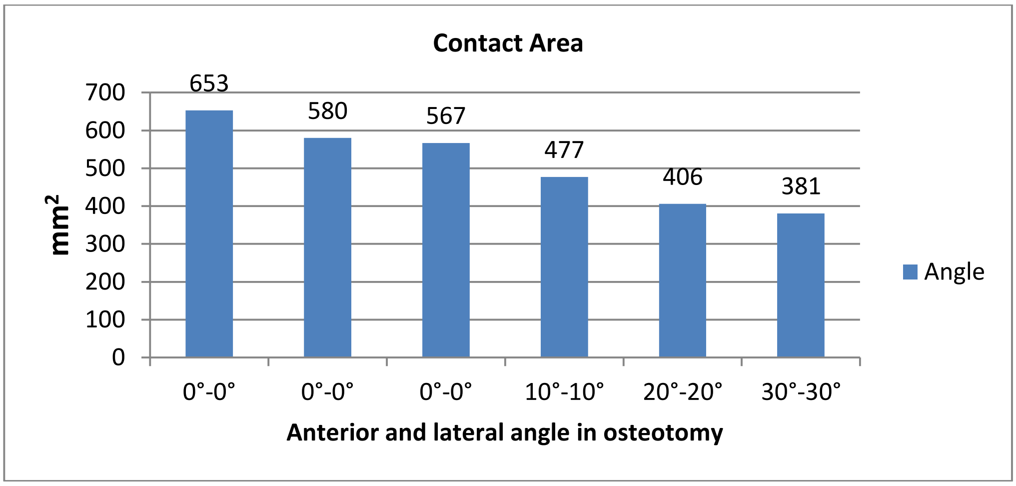

Figure 4 Contact areas measured

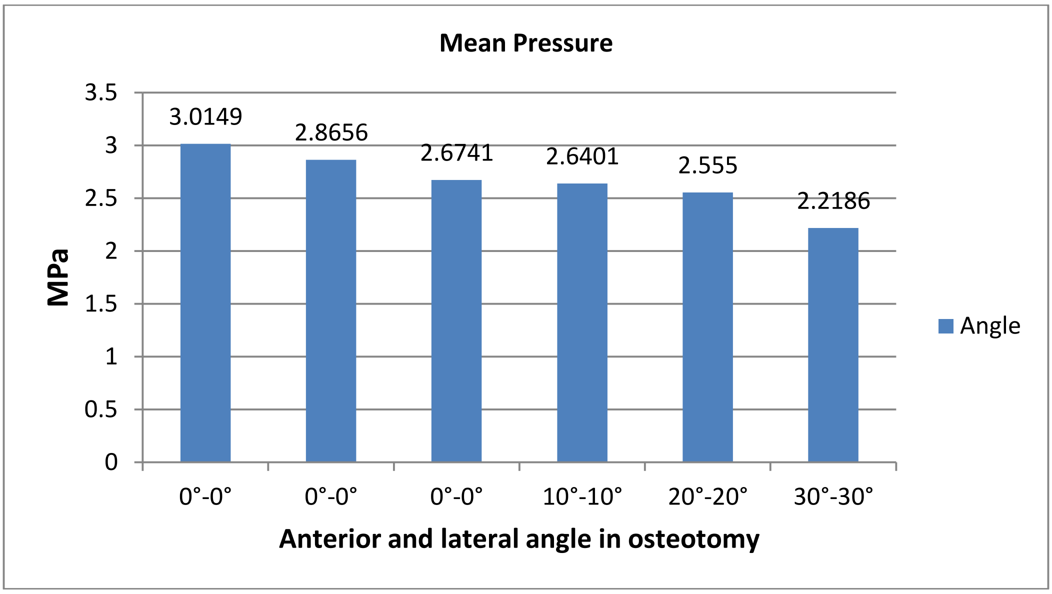

Figure 5 Mean pressures measured

4. Discussion and Conclusion

The average contact pressure expectedly decreases as long as osteotomy coverage angle increases but, the contact area decreases unexpectedly. However contact area is expected to increase as long as osteotomy coverage angle increases (Mavcic et al., 2002). The reason of this result is measurement capacity of pressure sensitive film. Low-grade pressure sensitive film with the capacity of 2.5-10 MPa is selected to measure the pressures. Lower pressure than 2,5 MPa can't estimated using pressure sensitive film. Because the colored stains over 2,5 MPa pressure are occurred on the pressure sensitive films after compression based on the contact distributions between the femur head and acetabulum. When osteotomy coverage angle increases, the pressure gradient is prone to decrease. However, lower pressure than 2,5 MPa couldn't calculated using pressure sensitive film in this study. This finding was not previously seen in any article.

Many studies in literature have presented contact stresses in normal and dysplastic hip joints using experimental studies using pressure sensitive film (Afoke et al., 1984; Sparks et al., 2005; Rothe et al., 1999; Pressel et al., 2008; Michaeli et al., 1997). But this unfairable condition hasn't been reported in the literature. When studying with pressure sensitive film, this must be considered by the researcher in terms of result accuracy.

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Conflict of Interest

No conflict of interest was declared by the authors.

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