QUANTITATIVE PREDICTION OF PROGRESSION OF ARTICULAR CARTILAGE DEGENERATION FOLLOWING INCONGRUOUS INTRA-ARTICULAR FRACTURE REDUCTION

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INTRODUCTION

Intra-articular fracture reduction is a very difficult orthopaedic procedure since it is widely believed that the residual incongruity can induce stress aberration in the articular cartilage and then provoke a mechano-response leading to degeneration of cartilage (secondary osteoarthritis).

The degeneration of cartilage is a chronic procedure. From a mechanical perspective, the neighboring healthy cartilage will endure elevated load since degenerative cartilage becomes more compliant. Therefore, healthy cartilage may degenerate with time, a cascading effect leading to whole joint degeneration.

Here, Discrete Element Analysis (DEA)[2] was used to quantitatively calculate the possible degeneration area in an acetabular fracture, as an example to show the effect of progressive degeneration when the cascade effect is taken into account.

METHODS

A hip joint model was created from the CT slices and the potential contact area was selected between the femoral head and acetabulum. [3] Treating the femoral head and acetabulum as rigid bodies, the region between them, *viz.* the cartilage, is represented as an array of linear elastic compressive springs. The springs' stiffnesses in the normal direction (Equation 1) depend on the cartilage modulus (E), Poisson ratio (ν) and thickness (h). Shear can also be addressed in DEA, but due to joint lubrication, the stiffness in shear here is assumed to be negligible.

$$k_n = \frac{E(1-\nu)}{(1+\nu)(1-2\nu)h} \qquad [1]$$

A trans-tectal displaced fracture model was created. A gait cycle with 16 instances was used to calculate the contact stress distribution. Cumulative pressure exposure (P_c) for the cartilage was then calculated [3]. The results were scaled to compare with literature on chronic cartilage pressure tolerance. [1]

The potential degeneration area is defined as any area with P_c large than 10 MPa-years. Here, a year was used as a time span. The cartilage modulus in any region with degeneration was reduced to only 20% that of normal. The same procedure was used to calculate the potential degeneration area in the next year and so on.

RESULTS AND DISCUSSION

For different residual step-offs (2.5, 2.0, 1.5, 1.0, 0.5 and 0mm), the cumulative pressure exposures were calculated for a 2-year time span. Also, progressive degeneration was calculated. (Figure 1)

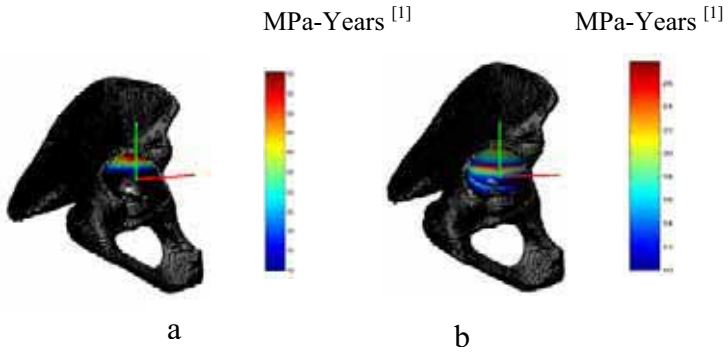

FIGURE 1 DISTRIBUTION OF CUMULATIVE PRESSURE EXPOSURE AT 2 YEARS, FOR A 2MM STEP-OFF
(a) Without progressive degeneration (b) with progressive degereration

Step-off (mm)	2-year Overpressure Area (mm^2) without cascade effect	2-year Overpressure Area (mm^2) with cascade effect
0	0	0
0.5	6.68	845.64
1.0	486.89	1688.50
1.5	576.34	1747.80
2.0	700.60	1798.10
2.5	988.94	1954.00

Table 1: Cartilage area experiencing over 10MPa-years of cumulative over-pressure (Total potential contact area = 3402.9mm^2)

Areas of cartilage degeneration are much larger when cascading progressive degeneration is taken into account. So, mechanical degeneration may substantially accelerate the pathogenesis of whole joint OA.

The percentages of the degeneration area are 24.8%, 49.6%, 51.4%, 52.8% and 57.4% of the available contact area. From this perspective, any fracture reduction with residual step-off greater than 1mm step-off faces high OA risk at a 2-year span.

REFERENCES

[1] Hadley et al: *J. Ortho. Res. 8:* 504-513, 1990 [2] Kawai et al: *Conf. Comp. in Civ. Engn.*: 1-16, NY ,1981 [3] Dai et al: *ASB 2004* , Portland, 2004

ACKNOWLEDGEMENTS

Supported in part by NIH AR46601