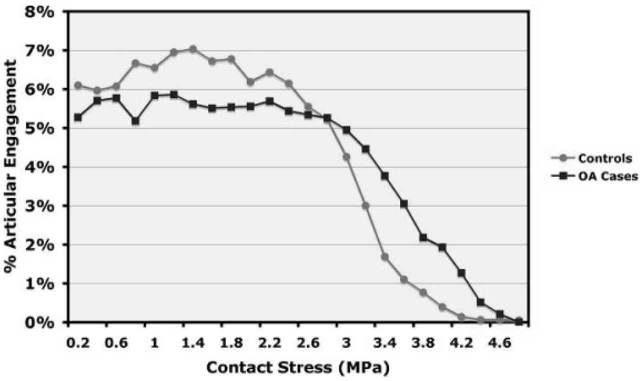
Conclusions: This study is to the authors' knowledge the first to identify risk for incident symptomatic knee OA by subject-specific biomechanical modeling. Using DEA was an efficient means of estimating subject-specific articular contact. The presence of differences in estimated contact stress by imaging 15 months prior to diagnosis suggests a possible biomechanical mechanism for the development of symptomatic knee OA.



Distribution of Articular Contact Stress.

120 KNEE AND SUBTALAR JOINT MOMENTS DIFFER IN ELDERS WITH AND WITHOUT KNEE OSTEOARTHRITIS

W. Kakihana[1], M. Akai[2], K. Nakazawa[2], K. Naito[2], S. Torii[3]. [1]*Ishikawa Prefectural Nursing University, Kahoku, JAPAN,* [2]*National Rehabilitation Center for Persons with Disabilities, Tokorozawa, JAPAN,* [3]*School of Sport Scineces, Waseda University, Tokorozawa, JAPAN*

Purpose: To compare the frontal plane knee and subtalar joint loading patterns in elderly females for characterization of the mechanical implications of differing radiographic grades of knee osteoarthiritis (OA).

Methods: Twenty-four subjects without knee OA (asymptomatic) and 19 age-matched subjects with symptomatic bilateral medial compartment knee OA walked at a self-selected cadence. We conducted three-dimensional motion analysis, femortibial angle measurement, and radiological assessment with Kellgren-Lawrence (KL) grade. Three-dimensional gait analyses were conducted with a motion analysis system (Vicon 512 System) operating at 60 Hz with 12 infrared cameras and 8 force platforms operating at 60 Hz. We investigated frontal plane angles and moments at the knee and subtalar joints, as well as moment arm of the subtalar joint for less affected right legs only of asymtomatic subjects and for more affected right or left legs of subjects with symptomatic knee OA. Moments were derived using a three-dimensional inverse dynamics model of the lower extremity. The average moments at the knee and subtalar joints were equivalent to the division of the area under moment-time curve and its time of application, respectively. Evaluations of the average angles at the knee and subtalar joints, and moment arm of the subtalar joint were performed by the same methods as for those applied for the average moments at the knee and subtalar joints.

Results: Subjects with mild (KL grade 2) radiographic knee OA demonstrated greater adduction moment (2.30%Bw×Ht, $P = 0.008$) and angle (3.4 degree, $P = 0.009$) at the knee joint than the subjects without definite evidence (KL grade 0 or 1) radiographic knee OA. In contrast, eversion moment (1.11%Bw×Ht, $P = 0.015$) and moment arm ($P = 0.037$) at the subtalar joint were smaller for subjects with mild (KL grade 2) radiographic knee OA compared with subjects without definite evidence (KL grade 0 or 1) of radiographic knee OA. There was a stronger correlation between the knee joint adduction moment and the subtalar joint eversion moment in the subjects without definite evidence (KL grade 0 or 1) of radiographic knee OA ($r = 0.37$, $P = 0.069$) than in the subjects with mild (KL grade 2) radiographic knee OA ($r = -0.07$, $P = 0.768$), but these correlations did not reach statistical significance in either group.

Conclusions: Radiographic knee OA appears to be related to functional gait alterations. Interventions for subjects with mild radiographic knee OA should therefore be assessed for their effects of on subtalar joint as well as knee joint during stance.

121 SPATIAL CORRELATIONS BETWEEN LOCAL IMPACT STRESS AND CELL DEATH DISTRIBUTIONS

C.M. Goreham-Voss, D.J. McCabe, M.J. Rudert, J.A. Martin, D.R. Pedersen, T.D. Brown. *University of Iowa Dept. of Orthopaedic Surgery, Iowa City, IA, USA*

Purpose: Studies of the cellular response of articular cartilage to impact loading typically assume uniform stress distributions across a flat impactor face, and evaluate resulting cell viability changes as being uniform within the impacted region. However, non-uniform stress and cell death distributions have been suggested in recent experiments. The purpose of this study was to develop a method to correlate the local variations in impact stresses with the resulting distribution of cell death, toward the goal of improved insight into the mechanisms that lead to cartilage degeneration.

Methods: A drop tower was used to impact a specimen of bovine articular cartilage and underlying bone with a brass impactor dropped from 54 mm. The impactor had a diameter of 6 mm, with an edge radius of 0.5 mm, resulting in a nominal area of 28.27 mm^2. A drop mass of 0.73 kg was used, resulting in an impact energy of 0.39 J. The osteochondral specimen measured 25 mm × 25 mm, with cartilage, subchondral, and cancellous bone thicknesses of 2.47 mm, 0.92 mm, and 3.94 mm, respectively.
Following impact, the cartilage was incubated for 3 hours, stained with calcein AM and ethidium homodimer for 1 hour, then imaged with a confocal microscope. The specimen was mounted on a custom-built XY stage allowing for precise registration of images. 9 image stacks, from the superficial 200 μm, were taken over the impact site, and reconstructed into a composite view of the impact site (Figure 1). An image analysis program (ImageJ) was used to calculate cell death fraction along a radial path from the center of the impact.

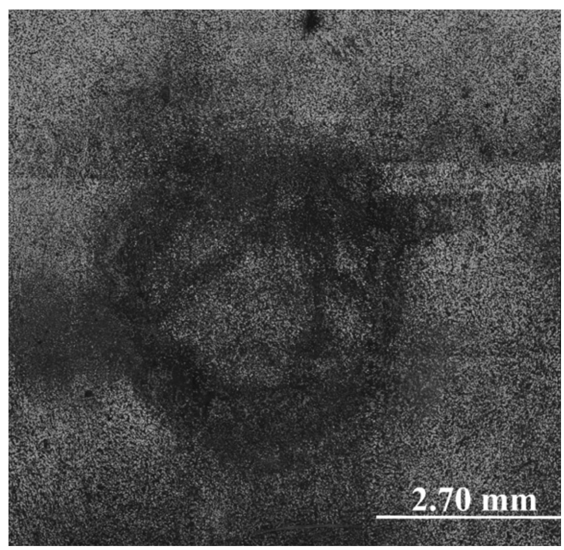


Figure 1. Confocal microscopy image showing the distribution of live (green) and dead (red) cells at the impact site.

An axisymmetric nonlinear contact finite element model of the impact was created in ABAQUS Explicit. The impactor was modeled as a rigid surface. The cartilage was modeled as a hyperelastic material (Ogden, $\alpha = 7.5$, $\mu = 1$ MPa) with viscoelasticity (Prony series expansion, $g_1 = 0.75$, $\tau_1 = 0.001$ s), a formulation previously validated. The cancellous and subchondral bone were modeled with linear elastic moduli of 760.3 MPa and 5.7 GPa, respectively, and Poisson's ratios of 0.4. The specimen thickness, impactor geometry, and impact energy corresponded to the experimental test.

Results: Several stress measures were evaluated along the surface of the FE model and compared to the cell death distributions from confocal microscopy (Figure 2). An annular pattern was clearly visible in both the stress and cell death distributions. Linear correlations with cell death fraction for shear stress, normal stress, and hydrostatic pressure were calculated to have R^2 values of 0.378, 0.551, and 0.728, respectively.

Conclusions: The hydrostatic pressure can be interpreted as the fluid pressure in the cartilage during impact. Pressure's high correlation with cell death raises the possibility that chondrocytes are influenced by changes in the surrounding fluid environment as much as by perturbations of the solid component of the extra-cellular matrix. Perhaps even more significant is the low correlation between cell death and shear stress. Shear stress is commonly thought to be a key parameter for chondrocyte viability. However, the results shown here indicate that normal stress and fluid pressure have a far stronger influence on post-impact cell viability. Future experiments using different impact energies and impactor faces should allow for better separation of different stress components and more precise understanding of the influence of stress magnitude versus stress rates.

This study was supported by a grant from the NIH (AR47653).

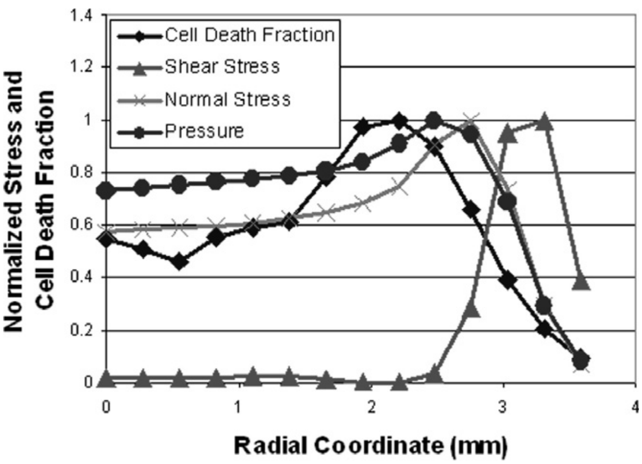


Figure 2. Comparison of cell death profile to maximum stresses.

122 EFFECT OF A PATELLAR BRACE ON THREE-DIMENSIONAL PATELLAR TRACKING IN SUBJECTS WITH KNEE OSTEOARTHRITIS

E.J. McWalter[1], D.R. Wilson[1], W.F. Harvey[2], K.A. Lamb[2], P. McCree[2], D.J. Hunter[2]. [1]*University of British Columbia and Vancouver Coastal Health Research Institute, Vancouver, BC, CANADA,* [2]*Boston University School of Medicine, New England Baptist Hospital, Boston, MA, USA*

Purpose: The aim of this study was to assess the effect of a patellar brace on three-dimensional patellar tracking (kinematics) in subjects with knee osteoarthritis.

Methods: We assessed three-dimensional patellar kinematics in 10 subjects with symptomatic radiographic patellofemoral knee osteoarthritis using a validated, quasi-static, MRI-based method. Each subject underwent 4 assessments of patellar kinematics: (1) no knee brace, no load, (2) no knee brace, 15% bodyweight (BW) load, (3) knee brace, no load, (4) knee brace, 15% BW load. The 15% BW load was applied axially through the foot using a custom designed, MRI compatible loading pedal. A standard patellofemoral brace was used for all subjects. Patellar kinematics (flexion, spin and tilt; proximal, lateral and anterior translation) were assessed using custom software (Matlab, the Mathworks, Natick, Ma) at 6 static angles over a range of approximately 35º of knee flexion. The error of the method is less than 1.02º for spin and tilt and less than 0.88 mm for translations. Splines were fit to each subject's data using the spcvr function in Matlab. Comparisons were made at 1º increments over the coincidental range of knee flexion between the no-brace and brace conditions, at no load and 15% BW load, using a paired t-test with Bonferroni correction for multiple comparisons ($p < 0.0042$).

Results: All of the 10 subjects had radiographic lateral patellofemoral OA (7 female, 3 male, 60.9±11.3 yrs, 89.5±19.3 kg) and seven had concomitant tibiofemoral OA (KL grade ⩾ 2). Under no applied load, the brace extended and medially tilted the patellae and shifted them distally, medially and posteriorly (Table 1). There was no difference in patellar spin between the no-brace and brace condition when no load was applied. Under 15% BW load, the brace extended and externally rotated the patella and shifted them distally, medially and posteriorly (Table 2). There was no difference in patellar tilt between the no-brace and brace condition when the 15% BW load was applied.

Conclusions: The largest effect of the brace was to produce more extended patellae in both no load and 15% BW load conditions, which suggests that the brace restricts the patella in flexion/extension. The more distal patellar position with the brace at 15% BW load could also be due to the restriction of proximal/distal patellar motion. Differences in patellar tilt were seen when no load was applied, but not when 15% BW load was applied, which may be due to the stabilizing effect of the active quadriceps muscle stabilizes on patellar tilt in the loaded case. While the effect of bracing on kinematics may appear small, the data was analyzed using the global mean difference and the effects of subject and knee flexion angle were not considered. However, small differences in kinematics have been observed between normals and patients with patellofemoral syndrome, which suggests that braces have potential for clinically significant changes in patellar kinematics.

Table 1: Paired t-test for the no-brace and brace conditions, under no load

Parameter	Mean Difference	t-Value	P-value	95% Lower CI	95% Upper CI
Flexion	2.7	20.970	<0.0001	2.4	2.9
Spin	0.1	1.994	0.0469	0	0.2
Tilt	−1.4	−14.856	<0.0001	−1.6	−1.2
Proximal Translation	0.8	9.797	<0.0001	0.6	0.9
Lateral Translation	0.5	14.850	<0.0001	0.5	0.6
Anterior Translation	0.6	19.945	<0.0001	0.5	0.6

Table 2: Paired t-test for the no-brace and brace conditions, under 15% BW load

Parameter	Mean Difference	t-Value	P-Value	95% Lower CI	95% Upper CI
Flexion	2.4	14.830	<0.0001	2.1	2.8
Spin	0.3	3.280	0.0011	0.1	0.5
Tilt	−0.2	−0.943	0.3462	−0.5	0.2
Proximal Translation	1.3	16.568	<0.0001	1.1	1.4
Lateral Translation	0.8	17.841	<0.0001	0.7	0.9
Anterior Translation	0.6	12.603	<0.0001	0.5	0.7

123 ADDITION OF AN ARCH SUPPORT IMPROVES THE BIOMECHANICAL EFFECT OF A LATERALLY WEDGED INSOLE

K. Nakajima[1], W. Kakihana[2], A. Hikita[3], M. Akai[4], T. Iwaya[4], K. Nakamura[1], **N. Fukui**[3]. [1]*Department of Orthopaedic Surgery, The University of Tokyo, Tokyo, JAPAN,* [2]*Department of Nursing, Ishikawa Prefectural Nursing Unviersity, Kahoku City, JAPAN,* [3]*Clinical Resarch Center, National Hospital Organization Sagamihara Hospital, Sagamihara, Kanagawa, JAPAN,* [4]*National Rehabilitation Center for Persons with Disabilities, Tokorozawa, Saitama, JAPAN*

Purpose: The use of a laterally wedged insole is a unique therapy for medial knee osteoarthritis (OA) which could change the loading within the joints. However, at present, the treatment is not widely accepted because of its limited efficacy. In this study, we investigated whether the addition of an arch support could improve the biomechanical effect of the laterally wedged insole.

Methods: The study was performed under the approval of the ethical committees of the institutes. Twenty healthy volunteers (11 males and 9 females; average age, 28.4 years) were enrolled in the study. Three-dimensional gait analysis was performed, and kinetic and kinematic parameters at the knee and subtalar joints were compared among the following four types of insoles; a 5 mm-thick flat insole (FLAT), a flat insole with an arch support (AS), a 6-degree inclined laterally wedged insole (LW), and a laterally wedged insole with an arch support (LWAS). The parameters were first compared among the insoles for the entire stance phase. Then the stance phase was divided into three sections of equal length, and the parameters were compared in respective phases.

Results: The knee adduction moment averaged for the entire stance phase was reduced by the use of LW and LWAS by 7.7% and 13.3%, respectively, from that with FLAT. The difference of the moment between LW and LWAS was significant ($p < 0.01$). When analyzed in respective phases, the reduction of the moment by the arch support was most obvious in the late stance (Figure 1). The comparison of the kinematic parameters revealed that LW tended to induce toe-in gait, and that trend was completely abrogated by the addition of an arch support. The increase in toe-out angle is known to raise knee adduction moment in the late stance. Thus, the difference of the moment between LW and LWAS could be ascribed to the change of the toe-out angle by those insoles. The analyses also revealed that LW tended to increase step width, and that such an increase was completely eliminated by the addition of an arch support to LW (i.e. LWAS). The wider the step width becomes, the more lateral the position of the ground reaction force would be, which could elevate knee adduction moment. Therefore, the reduction of step