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The relationship between subchondral bone strength, cartilage thicknees and contact pressure of the tibio-femoral joint

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Subkondral kemik kuvveti, kıkırdak kalınlığı ve tibio-femoral eklemin temas basıncı arasındaki ilişki

İnsan kadavrasından elde edilen 6 taze diz örneği test edilmiştir. Femoral tibial eklemde temas basıncı tibial plato kıkırdağına gömülmüş 1. 5 mm çaplı borucuklara bağlı transistör basınç ölçerlerle ölçülmüştür. Subkondral kemik kuvvetini ölçerken, 90° konik profili olan 2. 5mm taban çapı sivri bir iğne eklem yüzeyine dik açıyla sabit hızda (1 mm/sn) ilerletilmiştir. Sonrasında kıkırdak kalınlığı burguyla delerek saptanmıştır. Temas basıncı menisküler tarafından örtülmeyen bölgelerde yüksekti. Subkondral kemik kuvveti medial tibial platoda meniskler tarafından örtülmemiş alanlarda yüksekti. Lateral tibial platodaysa örtülmeyen ve örtülen bölgelerde yüksekti. Femur kondilindeki subkondral kemik kuvveti tibial platonunkiyle kabaca uyumluydu. Kıkırdak kalınlığının dağılımı subkondral kemik kuvvetine benzerdi. Bu sonuçlara göre, yüksek subkondral kemik kuvvetinin ve fazla kıkırdak kalınlığının aşırı strese maruz kalan bölgelere karşılık geldiği saptanmıştır.

Anahtar kelimeler: *Temas basıncı, subkondral kemik kuvveti, kıkırdak kalınlığı, diz eklemi*

The relationship between subchondral bone strength, cartilage thic knees and contact pressure of the tibio-femoral joint

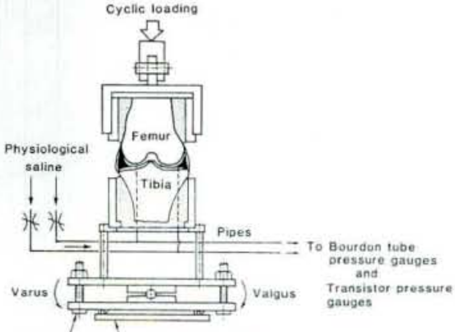
Six fresh knee specimens of human cadevera were tested. Contact pressure of the femoro-tibial joint was measured by transistor pressure gauges which were connected to pipes (1.5mm diameter) inserted in the cartilage of the tibia plateau. To measure the subchondral bone strength, a pointed-needle for penetration test, having a base diameter 2.5mm with 90 degree conical profile was advanced at the conant speed (1.0mm/sec.) at a right angle to an articular surface. Thereafter, cartilage thickness was measured by trepanning cartilage. Contact pressure was high at the areas uncovered by the menisci. The subchondral bone strengt showed high values at the area uncovered by the meniscus on the medial tibia plateau and at the areas uncovered and covered by the meniscus, which extended posteriorly from the uncovered area on the lateral tibia plateau. The distribution of the subchondral bone strength of the femur condyle was roughly congruous with that of the tibia plateau. The distribution of the cartilage thickness was similar to that of the subchondral bone strength. From these results, the areas of high values of subchondral bone strength and cartilage thickness were coincident with those on which high stress was applied.

Key words: *Contact pressure, subchondral bone strength, cartilage thickness, knee joint*

It is well known that the subchondral bone density reflects the stress to which the articular surface is exposed (7) and the atage of the joint condition (3). Also the bone strength is in correlation to the bone density and penetration force (4, 5). The aim of the present investigation was to examine the relationship between the subchondral bone strength, cartilage thickness and contact pressure of the tibia plateau and the femur condyle.

Material and method

Six fresh knee specimens of human cadavera were tested. In all six knee specimens, no visible degenerative changes of articular cartilage were apparent.



Figur I: Shematic drawing of zthe apparatus for measuring contact pressure

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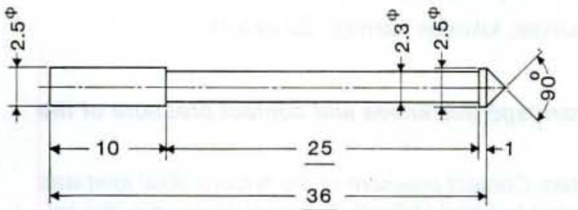
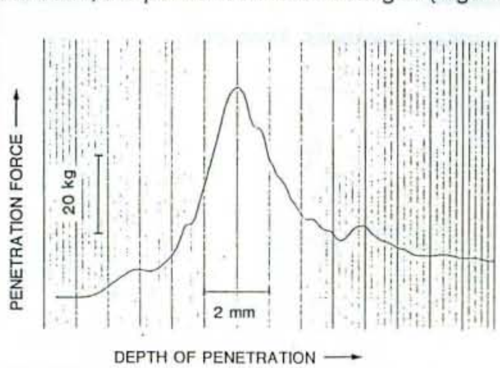
Prior to testing, the specimens were stored at -20° C. When required they were thawed slowly at room temperature. To measure the contact pressure on the tibia plateau under various load at 0 to 45 degrees flexed position, transistor pressure transducers and Bourdon tube pressure gauges were used simultaneously (Figur I). Both system were connected to the pipes inserted in the cartilage of the tibia plateau and back flashed pressure under cyclic load applied up to four times of the body weights for four seconds was led to them (6). After measurement of contact pressure, for assessment of the subchondral bone strength of the tibia plateau and the femur condyle, multiple penetration tests were performed. The needle for penetration had a base diameter 2. 5 mm with 90 degree conical profile (Figur II).



Figur II: Pointed needle for penetration

The needle was advanced at the constant speed (1.0 mm/second) at a right angle to an articular cartilage. As the tip of the needle penetrated cartilage and bone, the penetration force changed (Figur III).

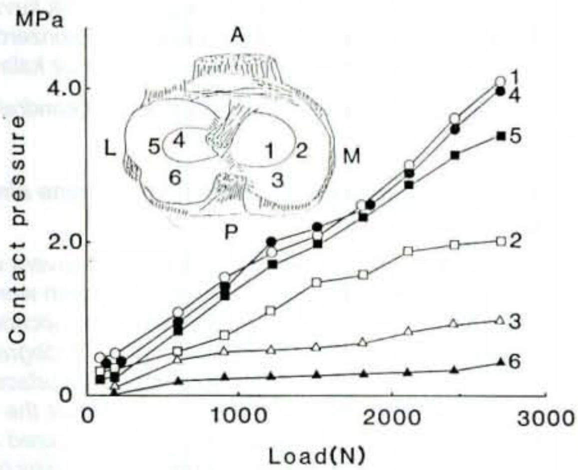


Figur III: Penetration force and depth relationship

Peak penetration force was referred as the penetration force at each point. The cartilage thickness of the tibia plateau and the femur condyle was measured after taking cylinder with subchondral bone at a right angle to an articular surface. To identify the measuring point of the subchondral bone strength and cartilage thickness, special devices were used for the femur condyle and the tibia plateau respectively. The interval between strings was 5 mm.

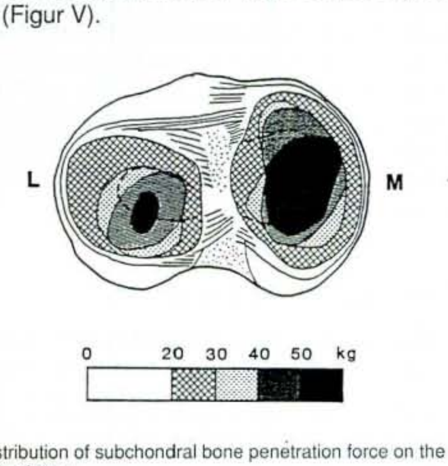
Results

At the knee extension with the intact menisci, the peak contact pressure increased roughly in proportion to to the load up to 4.2 MPa (Figur IV). The pressure of the cartilage covered by the meniscus gradually increased with load, but did not reached to 2.0 MPa, except near inner edge of the menisci. As the angle of the knee flexion increased, the position of the peak contact pressure moved posterior and contact pressure increased both in the areas covered and uncovered by the menisci.



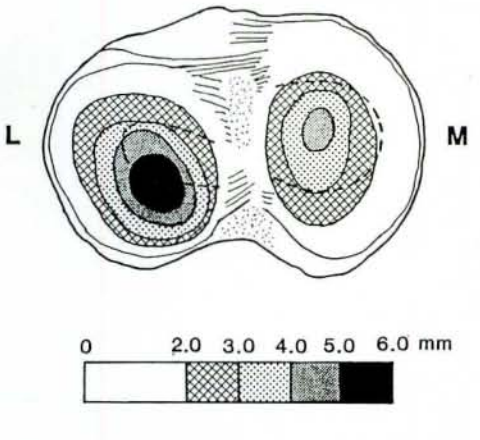
Figur IV: Contact pressure on the tibia plateau at the knee extension with the intact menisci.

There were considerable differences of penetration force from specimen to specimen. On the medial tibia plateau, the penetration force showed high values both in the areas uncovered and covereed by the meniscus (Figur V).



Figur V: Distribution of subchondral bone penetration force on the tibia plateau.

The area of high values extended anterior from the uncovered area. On the lateral tibial plateau, the penetration force showed high values both in the areas uncovered and covered by the meniscus, which extend posteriorly from uncovered area. Though the changes of the penetration force on the femur condyle were smooth from region to region, the distribution of the penetration force of the femur condyle was congruous with that of the tibial plateau. The maximum penetration forces of the tibia plateau were much higher than those of the femur condyle and there was strong, statistically significant linear relationship between them. The maximum penetration forces of the patellar face was much higher than those of the femur condyle. Again, there was strong, statistically significant linear relationship between maximum penetration force of the tibia and that of the patellar face. Cartilage on the medial tibia plateau was thick in the area uncovered by the meniscus (Figur VI).

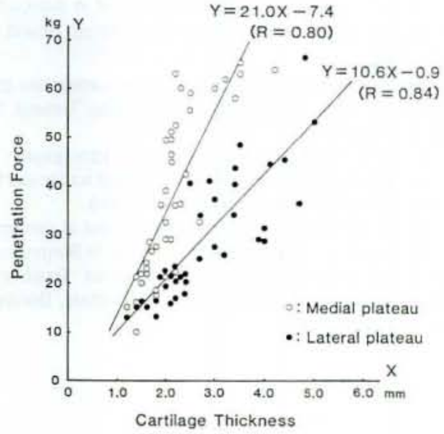


Figur VI: Distribution of cartilage thickness on the tibial plateau.

On the lateral tibial plateau, cartilage was thick both in the areas uncovered and covered by the meniscus, which extend posteriorly from uncovered area. The distribution of the cartilage thickness closely matched to that of the penetration force both on the tibia plateau and the femur condyle. There was strong, statistically significant linear relationship between the penetration force and cartilage thickness both on the femur condyle and the tibia plateau (Figur VII).

Discussion

In referring to the distributions of the contact pressure by Ahmed et al (1), Fukubayashi et al (2) and the present investigation, the distribution of the penetration force, namely subchondral bone strength is closely congruent with them. From these facts, the penetration force is closely connected with the contact in consideration to the movement of the strong



Figur VII: Relationship between subchondral bone penetration force and cartilage thickness on the tibia plateau.

contact area and internal rotation with the knee flexion. It is supposed that the relationship between the contact pressure and subchondral bone strength is the remodelling effect of contact stress on the subchondral bone through the medium of overlying cartilage under Wolff's law (8). There were some ratios between the subchondral bone strengths of the tibia plateau, the femur condyle and the patellar face of the femur. Supposing that the subchondral bone strength reflects contact stress as bone remodelling, there are probably some ratios between the stresses of the tibio-femoral joint and the patello-femoral joint.

The distribution of cartilage thickness was closely correlated to that of the subchondral bone strength and there was strong, statistically significant linear relationship between them. Namely, these facts show that areas of thick cartilage correspond to areas of high subchondral bone strength and high contact pressure. Thick cartilage spreads and relaxes stress to which subchondral bone exposed, leading to effect on remodelling of subchondral bone.

Conclusion

From these results, the areas of high values of subchondral bone strength and cartilage thickness were coincident with those on which high stress was applied in consideration of the movement of the strong contact areas and internal rotation of the tibia rotation with the knee flexion.

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