The ROTOTRANSLATORY motion: experimental studies, mathematical analysis, orthopedic device.

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Premise - Femoral and tibial movement is about, for the first 30° of flexion, the rolling of femur, between 30 and 135 degrees is associated with a progressive anterior translation of the femoral condyles. This means that the center of rotation of the knee is not fixed, but variable depending on the degree of bending joint

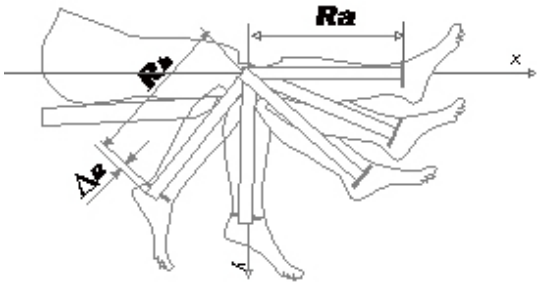
A brace for the knee should take into account this fact, largely confirmed by literature.

Purpose - The purpose of the study is to demostrate the mathematical basis of the project which are the foundation of a mechanic device that must respect the variability of position of the center roto-translatory of the knee.

Materials and methods - We used a "Leg extension" on which we added a system for measuring the position of the fibular malleolus to the (fixed) center of rotation of the machine. This measure in order to predict the apparent shortening of the leg in flexion. We chose to take the malleolus as a reference distance of the tibial plateau for the difficulty of a direct measurement. Given that, on the sagittal plane, the initial center of rotation of the knee coincides with the intersection of the x,y axes, on this basis we can say that in the full knee extension the x-axis of the leg js co-aligned with the x-axis of the femur. Starting from the hipothesis that in flexion of the knee, the istantaneous center of rotation (P) changes its position relative to the tibial plateau, approaching in the same way, we wanted to quantify the extent of this shift. For this purpose we used a "leg extension" associated with a system for measuring the distance between the fixed center of rotation of the machine and the apex of the lateral malleolus of the leg obtaining an indirect measure of the displacement of the center of rotation relative to the tibial plateau.

Calling R_a the measured distance with the knee extended and R_b that measured with the knee flexed, we concluded that the Δ_R corresponding to R_a- R_b.

The study was carry out on 83 men between 16 and 19 years old (average height cm 173,8 ± 5,89) . Detections were made in the extention, at 30,40,90 and 135 degrees of flexion.



Results - The results have been collected in table 1 .

Tab. 1

Angle flex	0	30	45	90	135
X Δ_R	0	0	0,04	1,25	4,99
δ	0	0	0,005	0,22	0,35

They show that the radius of rotation of the knee remains constant up to about 30 degrees of flexion (circular trajectory). For angles above 30 degrees the radius of rotation decreases the value Δ_R.

In other words ,the movement of flexion of the knee after an initial circular trajectory associates a sliding highlighted by the previous decrease of the distance between the center of rotation and the tibial articular surface. The displacement of the point P for first 30 degrees can be represented by the equation:

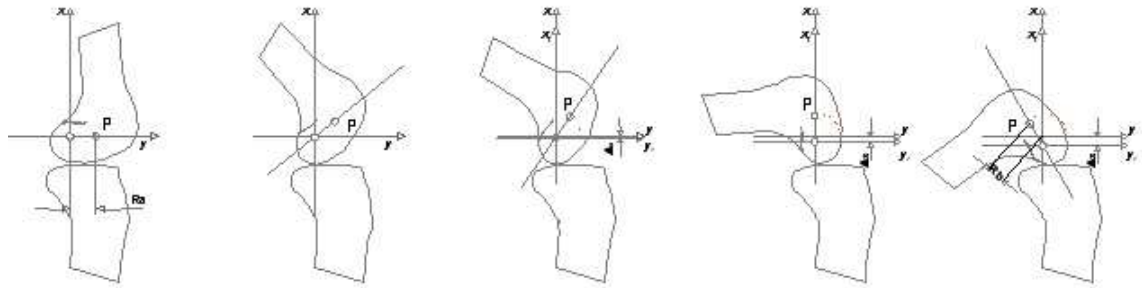
$$x^2+y^2=r^2 = R_a^2$$

which corresponds to a circle and for the next range of motion, until 135 degrees of flexion, by the equation:

$$x = x - x_1 = (R_a - R_b) \cos ø$$

It seems important to note that, when Δ_x is small enough compared to R_a, moving the center of rotation along the axis X can be neglected.

We then built a mechanical device that allows the projection on it of the rotation center of the knee mimics the physiological movement of it.



This was achived by inserting two pins on a first plante (femoral): a central pin placed at the intersection of the axes x,y and a peripheral one placed at the point P. On a second plate (tibial) , there are also two openings, one peripheral with a circular path for the first 30 degrees ,which assumes a spiral trend similar to the pathfollowed by the point P and a centrel one , that originates at a point corresponding to the intersection of the axes x,y with an extension along the x axis equal to Δ_x as calculate above.

This mechanical system, when used as a hub for a knee brace , is therefore respectful of the dynamic relationships of the articular, bones and capsule-ligamentous components.

Conclusions - The mechanical device repeats the roto- translatory motion of the knee and can be used with advantage in all orthopedic rehabilitation equipments, which assist flexion-extension of the knee movement.

In fact, it does not creat conflicts between the physiological and mechanical trajectory which could trigger voltages damaging to traumatized organs.Further reflections on the parallel knee/device have given rise to the belief that the roto-translatory motion should also apply to an assement tool for a real measure of the degree of flexion-extension of the knee.