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Proposal for hip prosthesis with stress-breaker

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ABSTRACT: The Authors, taking into account the fact that hip prosthetic implant mobilization frequently occurs due to excessive stress exerted on bone-prosthesis interface, suggest using prosthesis having stress-breakers, capable in reducing the loads exerted on the implant. There are some hip prosthesis in design which have a descharge force system in the cotyloid, in the neck and in the prosthetic stem. Some technical problems are not yet solved, expecially concerning the wear and tear, the friction and the lubrication of the stress-breakers. (Hip International, 1992; 2: 17-20).

KEY WORDS: Hip biomechanics

In the human skeleton, the hips represent the most frequently stressed WBS that during normal deambulation may reach values of thousand Newton.

In orthostatism, in bipodal stance hips represent the WBS of head, trunk and upper limbs (viz. 62% of b. w.). The body center of gravity lies on a sagittal plane perpendicular to the average point of the segment joining the two centers of the femoral heads, but in a more cranial position as to the same segment. With a symmetrical WBS, each hip bears a load accounting for 31% of b.w.. In monopodal stance the strained hip bears weight (P) of head, upper limbs and counterlateral limb (81% of the total b.w.).

The body center of gravity lies on a plane perpendicular to ground that passes through the strained foot, while the partial center of gravity (S5) relative to the entire body (except for the lower strained limb, viz. the actual load compressing the hip joint) tends to move laterally crossing the axis of the pubic symphisis; so P acts eccentrically on hip and pushes pelvis down and laterally, adducting it on femur. This pelvis collapse is counterbalanced by the action of abductor muscles of the strained hip, developing force M.

In fact, a primary lever is moved where the fulcrum is the center of the strained femoral head, the resistant force is P while the pushing force is M. For equilibrium, moments of two forces must be equal, viz. bpP= bmM (Fig. 1)

In a condition of static equilibrium, the resulting force (R) affecting the strained hip corresponds to the vectorial sum of P and M.

According to Pawels, bp is about three times longer than bm, so to maintain the equilibrium M must be about three time longer than P.

During deambulation, each hip temporay becomes the P WBS, because of the alternating phases of the monopodal stance occurring in gait, but suffers also the inertial force (D) due to the S5 acceleration.

It results that to maintain the equilibrium the action of abductor muscles must counterbalance strain respresented by the sum (K) of P and D; in other words, the moment of M must equal moment of K (Fig. 2).

In a normal hip, M acts as a lever arm of about 4cm forming a vertical angle of about 21°, while R forms an angle of about 16° and during deambulation it varies from 1.5 to about 5 times b.w., this reaching values of several hundred kilos.

Finally, emphasis must be given to an element that has a fundamental role in determining strain of a normal hip-joint, viz. an absolute shortage of friction (0.007 according to Barnett and Cobol, 1962;

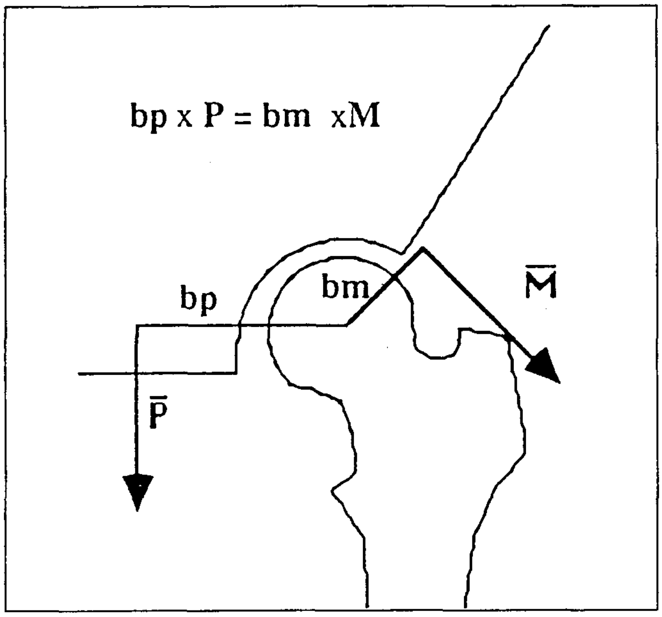

Fig. 1 - *Well-balanced hip-joint system.*

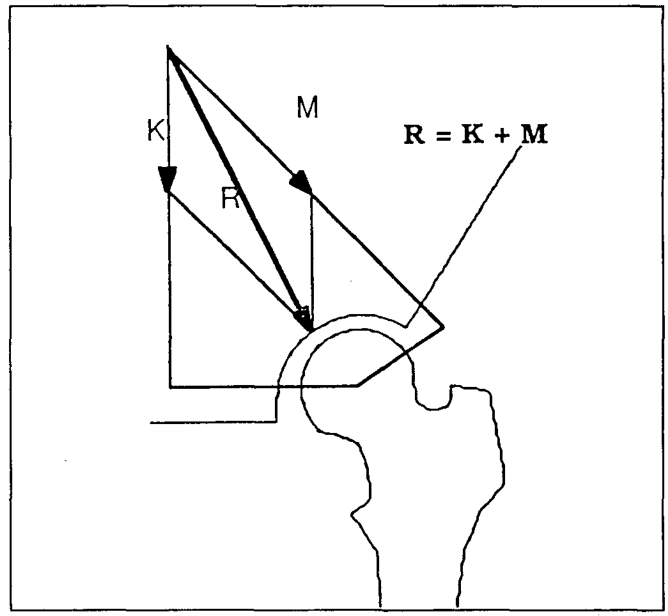

Fig. 2 - *Forces stressing the femoral head.*

0.002 according to Radin et al., 1970). The direct effect of this absolute shortage of friction is a non-influence of the cephalic ray on the value and distribution of the articular stress.

On the contrary, as for prosthetic hip a friction between the cephalic and cotyloid components always exists that even if minimum causes a further worsening of the stressing condition, so that generally forces straining the prosthetic hip are always superior to those affecting a normal hip in the same morphologic conditions.

One of the primary technical problems occurred about thirty years ago, during the first hip prosthesis mounting concerned materials wear in particular for "gasket" that ensures a very good contact between the cotyle and the prosthetic head. At first, materials such as teflon were used because of their minimum coefficient of friction, but then they were left apart by reason of an excessive mechanical wear. Recently, a good compromise between wear resistance and lubricant property has been reached thanks to high molecular weight polyethylene. In other words it can be assumed that today's industry provides for very sophisticated prosthetic models offering a high mechanical resistance and an excellent functionality.

Moreover, there are still unsolved problems such as those linked to the implant bioattachment.

Since many years our Clinic has been conducting several investigations on bone prosthesis interface. Our concern in the matter is supported by the fact that even when operation is excellently made, also from the technical point of view, when using the biological implant or that requiring acrylic cement, frequently at some months or years from operation, prosthesis mobilizations occur either for the femoral or the cotyloid components, or both.

This phenomenon, a part from any clear sign of errors in the surgical technique, may be explained by the fact that sometimes the bone-prosthesis integration doesn't allow to support frequent mechanical stresses of several thousand Newton.

Obviously, a reduction in compressive force on the bone-prosthesis interface will certainly result in a statistic decrease in prosthesis mobilizations.

Consequently our purpose was to find new ways to reduce stress compressing the prosthetic hip. After long-term considerations it can be emphasized that only too little can be made to modify either the surgical technique, design characteristics or prosthesis construction materials since in both case the state of the art has been reached. More-

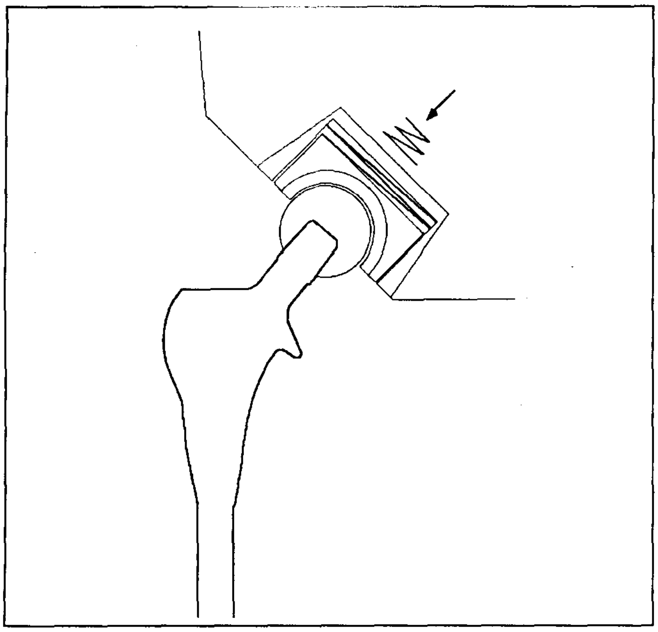

Fig. 3 - *Stress-breaker applied to the acetabular component.*

over, we observed that up to now researches were aimed at improving the prosthetic implant making it more biologically respondant to the natural hip.

At present, our goal is to propose an alternative line of study: instead of imitating nature, it should be better to use "outsider" methods for human body.

On our opinion a system relatively simple to realize aimed at reducing stress affecting the bone prosthesis interface, is that to introduce "stress-breakers" in the prosthetic hip, systems largely diffused in other non-biological machinery.

The stress-breakers should absorb part of the stress, diverting loads to other mechanical parts able to support them easier, and avoiding their distribution on the most crucial points, or at least reduce as much as possibile stress compressing the bone-prosthesis interface.

We considered also the opportunity to apply these systems to the acetabular and femoral components.

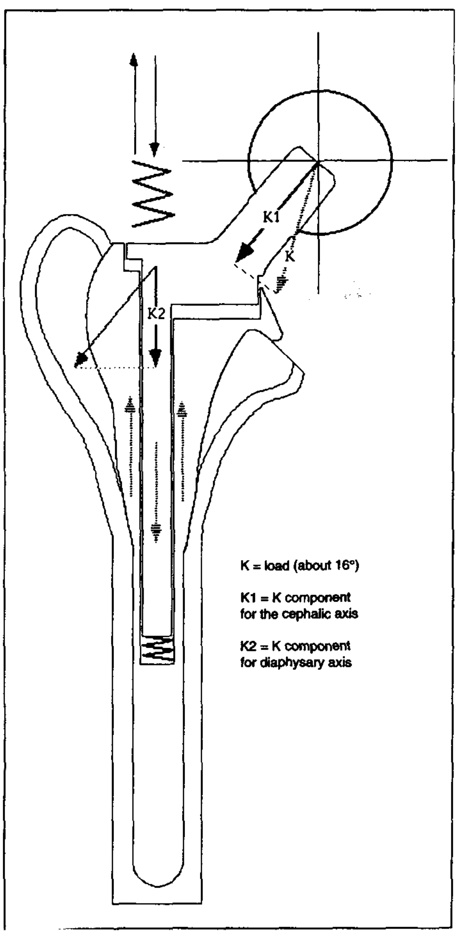

Fig. 4 - *Stress-breaker inside the prosthetic stem.*

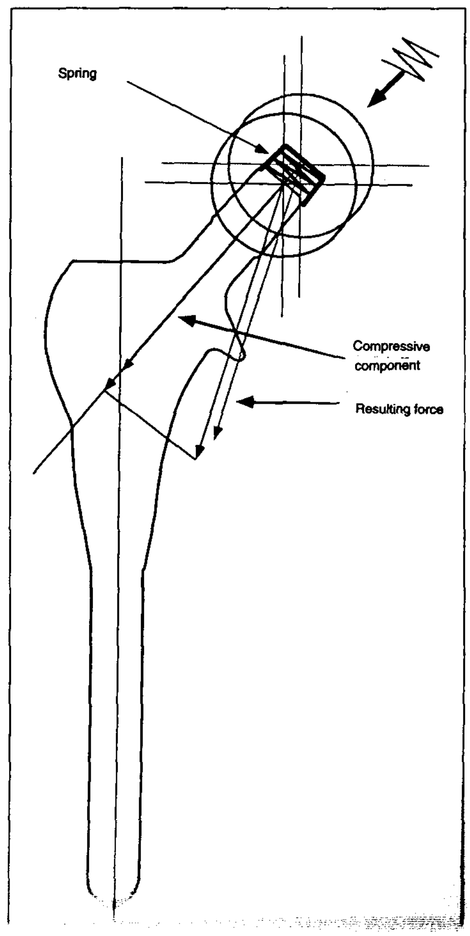

Fig. 5 - *Stress breaker in the prosthetic neck*

The following figures show some project examples.

As for the femoral component we provided for two alternatives, viz. that to apply the stress-breakers between head and neck or in the stem. In the first case the mechanical realization is probably more simple, though the stress-breakers operation seems to be more crucial. As for the second case, besides major constructive problems the possibility exists to realize a better stress distribution.

CONCLUSIONS

Considering the high incidence of hip prosthesis mobilizations due to inadequate integration with the femoral and cotyloid tissues because of huge stress affecting the bone-prosthesis interface, some alternative strategies are under study aimed at reducing stress affecting the prosthetic implant. The most interesting solution should be probably that providing for prosthesis equipped with stress-breakers.

Our research is now focusing on stress-breaker systems to be introduced either into cotyle, neck or prosthetic stem.

Even though theoretically simple to realize, the project implies serious technical constructive problems among which those linked to the forces discharging system wear, internal frictions and lubrication systems emerge.

The project is still under study and the practical realization of this new system will take some time before being applied.

Moreover on our opinion this problem is of certain concern and maybe it represents one of the few ways to obtain a further improvement in the ultra-advanced prosthetic systems.

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