EXPERIMENTAL STUDIES OF HIP REPLACEMENT

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Abstract

Our work was focused for a new design solution of hip prosthesis. Being well known that the slide friction coefficient value is higher than the rolling coefficient is was created hip joint prosthesis with rolling bodies. The external carcass, balls and femoral pieces are manufactured from same materials – CoCr alloy. As a result of this solution, the articulation will work similar to a bearing having a “compensation space”. The value of friction coefficients obtained are 0.12 – 0.20 respectively 0.006 – 0.008 in serum.

1. Introduction

Are well known the problems that appear of total hip joint prosthesis – wear processes, cement detachment, etc /1/.

Our work was focused for a new design solution of hip prosthesis having rolling bodies.

A comparative experimental study between a classic artificial joint and the new prosthesis will be presented in our work.

2. The new solution

The new hip joint prosthesis is presented in fig 1.

Our solution offer the possibility to eliminated the sliding friction by using rolling bodies /2/. The number and balls size was calculated based on dynamics local capacity. We consider in our calculus a normal loading of 1.8 kN, the angular extent of the loaded zone 30°.

As you can see in fig 1.b, the balls fill almost all the space between cothiloid piece and femoral sphere still remaining an empty space a little bigger than diameter of a ball. As a result of this solution, the articulation will work similar to a bearing having a “compensation space”.

When meets the carcass, the ball from the head of row will tend to be blocked, and in this way, the closed balls will be pushed to the empty space constructively let. In this way the balls will circulate. The ball migration through the constructive created space, eliminate the possibility to be blocked.

Fig. 1 Hip prosthesis with rolling bodies
3. Experimental studies

For the laboratory study of the wear and friction process of rolling hip joint prosthesis an experimental stand was created (fig.2). For the experiments have been used oscillation frequencies of 1 Hz and 2 Hz. The value of friction coefficients obtained are 0.12 – 0.20 respectively 0.006 – 0.008 in serum. A conventional prosthesis was tried on the stand in same experimental condition as our model. On can notice that the values of strength and friction coefficient (in dry conditions) are inferior those obtained for conventional prosthesis: 0.25 – 0.35.

As a conclusion we can affirm that the introduction rolling bodies leads to the friction diminution in articulation.

The friction pairs and the stress distribution who action over it, are graphic represented with the computer concomitance with experimental test.

A part pivot sphere, having a reduced number of rolling bodies placed over it is graphic presented in fig 3a. Similar, the cothiloid piece having the balls placed inside are represented in fig. 3b and 3c show the balls in contact one with the other. The details have only a qualitative mining.

The normal stress distributions of ball contact with pivot sphere are represented in fig. 3d. Similar, is represented in fig. 3e the distributions at the contact with cothiloid piece. From fig. 3f we can observe the direction changing of normal stress of slight motion of balls. It is known that the maximum of the stress $\tau_{xy}$ values at a depth $y$ of contact area is $0.31 \, p_{\text{max}}$ for the most challenging situation for a cemented prostheses are when the foot sole touches or not the soil ($v=0$, static friction). This is available when the motion starts and in presence of normal loading ($y = 0.48r$, where $r$ is contact area radius).

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A distribution of normal and sharing stress in articulation with rolling bodies are showing in fig.4. Because the wear rate can not be quantified by conventional methods (gravimetric, volumetric) a global studies is available by vibration spectrum analysis. This method offers only a qualitative result about the moment when the wear has a significant influence in functionality.

For conventional prosthesis we have a vibration spectrum modification after 1 million cycles. For prosthesis with rolling bodies we can not notice vibration spectrum alteration after 5 million cycles (fig.5)
4. Conclusion

The studies and the experimental researches have demonstrated the following:
- the total hip joint prosthesis are supported to a strong mechanical strain who deteriorate it. The friction efforts have a high value who determine the cement detachment in time of the cothiloid piece;
- in accordance with the experimental conditions, the friction coefficient varies between 0.12 – 0.20 in dry conditions, respectively 0.006 – 0.008 in serum;
- the introduction of rolling bodies leads to the friction diminution in articulation. As a result, the shearing stress will be damped in cothiloid piece material at 1.8 – 2.4 mm depth (for experimental conditions);

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5. References

/2/ Căpitanu L. Florescu V Some aspects concerning the strings of the pivot type articulation having rolling bodies and those influence in friction and wear process, with application in orthopedic implants. 7-th International Conference on Tribology, p366 – 373, ROTRIB '96
/3/ C’pitanu L., Florescu V., Petrescu F., Tribological aspects of a new design of hip prosthesis with rolling elements having, 7th International Conference on Tribology, september 2000, Budapesta, p191-194