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SPHERICITY EXAMINATIONS OF ARTHROPLASTIC TOTAL HIP PROSTHESES

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High requirements are put on the materials used, and the design and production of artificial hip joints. Important design features are not only tissue compatibility, mechanical stability, wear and corrosion resistance, but also such apparently simple factors as shape and production tolerances. Although to a certain extent friction and wear, as well as mechanical stress caused by shock and frictional torque, will inevitably occur, every possible precaution ought to be taken to reduce these detrimental effects to a minimum.

One of these harmful influences on the satisfactory functioning of a total hip prosthesis is the deviation of one or both of the articulating surfaces from true roundness. Wilson & Scales state that only recently has the importance of geometry and surface finish been appreciated. They believe that in a number of cases of early postoperative loosening the cause was the high initial torque, which was caused by:

1. site of bearing area in the cup,
2. irregular geometry of bearing surfaces of the cup and head, and
3. poor surface finish.

These investigators state further that the more perfect the finish of a bearing has to be, the higher the cost of the components will become and thus there must be a compromise between that which is theoretically desirable and that which is economically possible and clinically satisfactory.

We feel that the highest possible technical standard has to be achieved in order to avoid catastrophic failures caused by seizure under load and a following loosening of the artificial hip replacement. There-

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fore, an experimental examination of the two different types of artificial hip joints mainly being used in our hospital—McKee-Farrar and Weber-Huggler—was carried out.

It is well known that all technical surfaces show a certain amount of irregularities caused by protrusions, indentations, edges and irregularly slanted planes. As will be evidenced further down, our measurements indicate that the assumed spherical surfaces of the prostheses in fact exhibit irregularities such as spikes, small prongs, indentations and nonspherical planes of variable size. These deviations from the true sphericity cause high "Hertz" pressures between the articulating surfaces on one hand and high frictional torque on the other.

The natural consequence is inadmissably high wear, and the danger of postoperative loosening of acetabular cup or femoral shaft or both.

METHODS

Measuring device and examinations

The "Talyrond 100" is a precision instrument for measuring roundness (Figures 1 and 2). The principle of operation is illustrated schematically in Figure 1, which is essentially self-explanatory.

However it is important to emphasize the following details:

1. The radii of the graphs on the recorder charts (see Figures 4 and 5) bear no relationship to the radius of the workpiece.
2. Roundness evaluations by means of the recorded graphs are independent of their radii.
3. The graph is not to be regarded as a true cross-section of the workpiece on a greatly enlarged scale. The reason for this is that while the radial magnification is large (e.g. × 2000), the circumferential magnification is often less than × 1 (i.e. actually a reduction dependent on the size of some workpieces.
4. There is a direct angular relationship between the graph and the workpiece because the chart rotates at the same angular velocity as the turntable, both being driven by the same non-slip belt. Therefore angular positions of irregularities on the workpiece are coincident with the roundness deviations on the chart.

Departures from roundness are quoted as the difference between the largest and smallest radii of the sample profile. To find the centre of the minimum condition which establishes smallest radial difference one has to position two concentric circles of a polar jig on top of the diagram. Two requirements then have to be fullfilled: the graph must be entirely enclosed by the circles, and the circles must have minimum radial separation.

Due to the set magnification the graduation of the polar template corresponds to the true irregularity-amplitudes (μm) of the sample. The instrument can record up to × 5000 magnification, the accuracy of assessment being 0.4 μm. In accordance

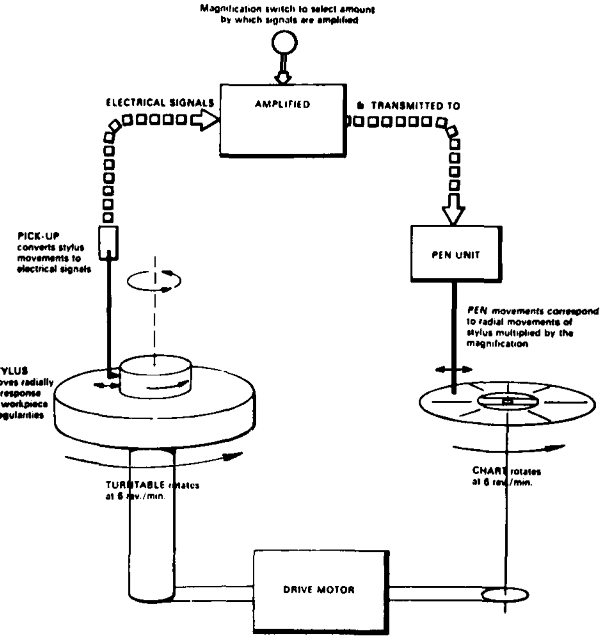

Figure 1. Schematic diagram showing principle of operation.

with the deviation from roundness which was considerably high in a number of measured prostheses, only a maximum of × 1000 magnification could be recorded in our examinations. As was mentioned above, two types of total hip prosthesis—McKee-Farrar and Weber-Huggler—have been examined. The McKee-Farrar total hip prostheses were produced by three manufacturers (marked "1", "2" and "3"). They were supplied from several contractors to obtain highest possible statistical dispersion. The Weber-Huggler prosthetic implants were made by only one manufacturer (marked "4"). 24 endoprostheses of is type supplied from several contractors were tested.

The nominal diameters (manufacturer's specification) were divided into two categories:

size 1: $1^5/_8$″, $1^9/_{16}$″, 42 mm diam.
size 2: $1^3/_8$″ diam.

Roundness was measured in the horizontal planes depicted in Figure 3 (the distance from pole to centre of the head being called h and the coordinate centre of head and cup being identical):

Head: plane A at 0.1 h
plane B at 0.75 h
Cup: plane C at 0.1 h
plane D at 0.5 h
plane E at 0.75 h

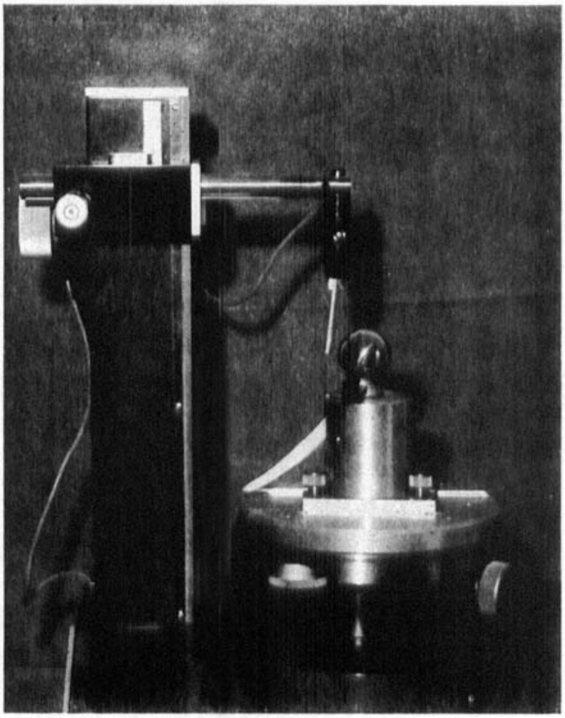

Figure 2. Pick-up and turntable.

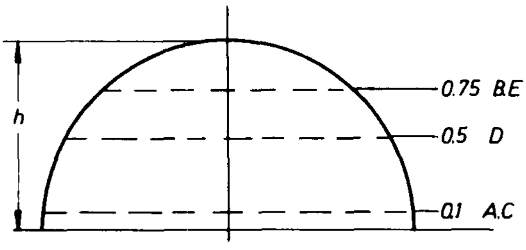

Figure 3. Measuring planes.

It must be mentioned that measurements in the frontal and sagittal plane could not be carried out since the "Talyrond 100" requires one complete revolution for each measurement. This however can obviously not be done for the reason of the particular shape of the specimens (incomplete spheres of head and cup).

RESULTS AND CONCLUSIONS

A total of 194 "Talyrond" recordings of an aggregate number of 39 prostheses (head and cup in two and three planes respectively) were taken, giving an overall number of evaluations of more than 2000, taking into account the partition of the polar recording chart into twelve angular sections. Examples are shown in Figures 5 and 6. According to the generally accepted definitions of sphericity or nonsphericity respectively (e.g. DIN-Norm number 7184) maximum deviations of the arithmetic means of each sample plane can be utilized as well as variance or standard deviation. Actually the first quantity is a measure of smaller surface irregularities such as protrusions, spikes etc. whereas the latter quantities lead to numbers which have a relation to the entire surface deviation from the true sphericity of an ideal body. Thus both quantities were derived from the above recordings. Figure 4 shows the arithmetic means and the actual maximum deviations of the articulating surfaces in the depicted planes A, B, C, D and E. As can be seen clearly, there are large differences in the prostheses of the McKee-Farrar-type among the manufacturers. Although the Weber-Huggler-type prostheses exhibit relatively small roundness deviations this is not at all due to the different kind of material (plastic-head, metal-socket) but rather to the high production standards of the manufacturer "4", the same proving true for the all-metal prostheses of manufacturer "3".

A similar picture appears for the standard deviations also taken from the above-mentioned polar diagrams. It does not seem to be very useful to detail all of the 194 standard deviations evaluated. However the essential result is that

1. head and cup exhibit a different quality in all prostheses,
2. there is no trend with respect to a superiority of head or socket in comparisons between the various manufacturers, and
3. the standard deviations calculated for the head (planes A and B) range from 0.1 μm to 40 μm; the ones for the cups (planes C, D and E) range from 0.1 μm to 21 μm.

Although these results show a rather large variety in quality with respect to roundness it can be concluded by these figures that two manufacturers ("3" and "4") are capable of producing prostheses with roundness deviations of the articulating surfaces of less than 3 μm.

The success of an implanted total hip prosthesis does of course not only depend on the sphericity of the articulating surfaces. In reality it is very difficult to lay down exactly the influence of nonsphericity on wear and friction. To minimize this detrimental influence, however, an optimum accuracy of surface geometry i.e. roundness and finish

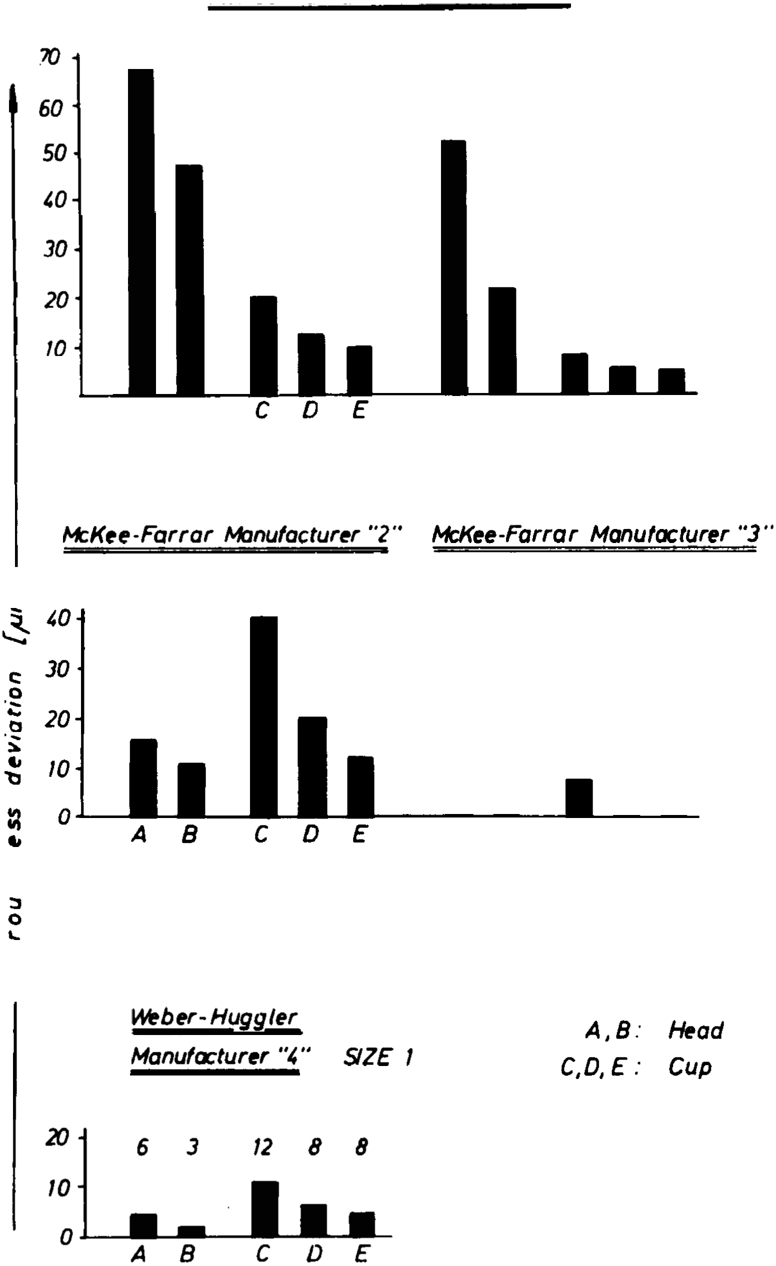

Figure 4. Arithmetic means (column diagrams) of the roundness deviation in five horizontal planes A, B, C, D, E. Numbers on top of the columns show the actual maximum values.

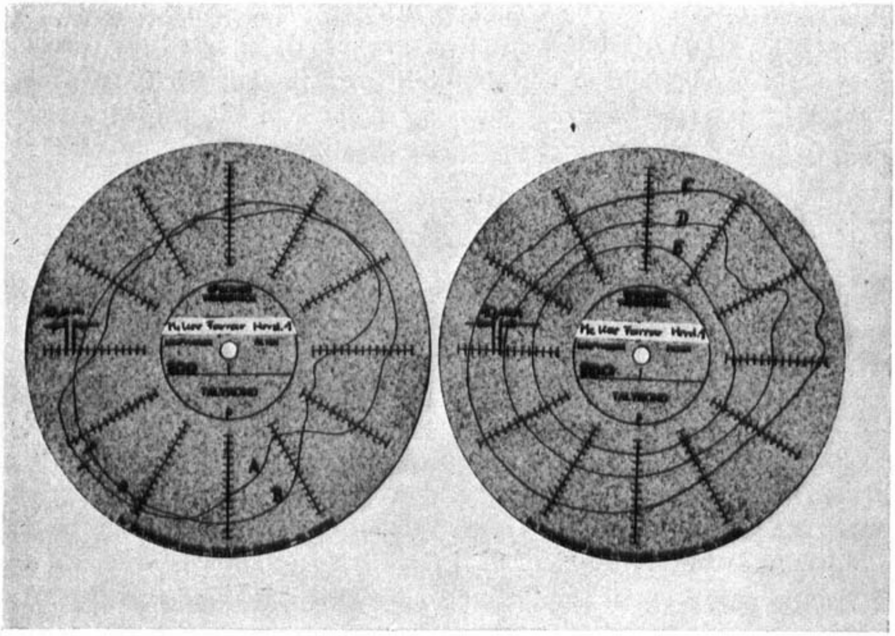

Figure 5. Graph of a total hip prosthesis (head left and cup right) of manufacturer "1" × 200 Magnification.

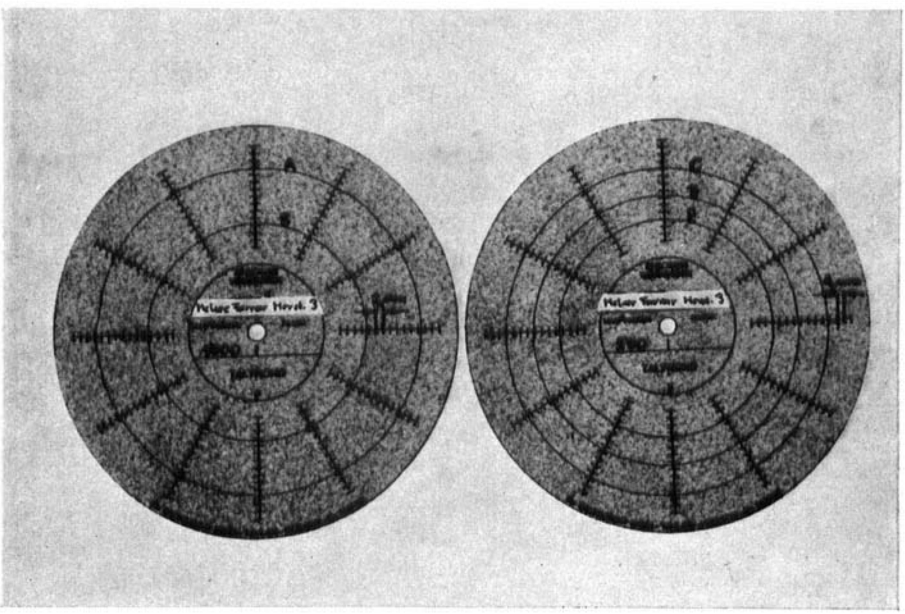

Figure 6. Graph of a total hip prosthesis (head left and cup right) of manufacturer "3" × 1000 Magnification, × 500 Magnification.

attainable by present-day technical standards has to be exacted. We hold that a standard deviation of true sphericity of less than or equal to 3.0 μm for both head and cup will prevent high frictional torque caused by initial or eventual jamming under load and will thus give a high degree of reliability of the entire prosthesis.

SUMMARY

Friction and wear of total hip prostheses may lead to tissue-damaging reactions and loosening of implanted parts. An equally serious influence on the artificial joint may be exercised by the degree of nonsphericity of the articulating surfaces. The present paper investigates the actual roundness of total hip prostheses of the McKee-Farrar and Weber-Huggler types, of which samples from a variety of manufacturers were inspected. The results point out that several commercially available prostheses deviate from sphericity to an extent which cannot be accepted taking into consideration high frictional torque and the danger of loosening of joint components. It is suggested that the maximum tolerable standard deviation of sphericity of the articulating surfaces should be 3.0 μm.

REFERENCES

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