Accuracy of total knee replacement bone cuts using a conventional ancillary system: 300 Innex® total knee arthroplasties

Précision des coupes osseuses dans l’arthroplastie totale du genou à l’aide d’un ancillaire conventionnel

Trois cent poses consécutives de prothèses Innex®

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RÉSUMÉ

À l’heure où la chirurgie des prothèses totales du genou peut être assistée par ordinateur, il est important de disposer d’études sur la précision obtenue avec les ancillaires conventionnels afin d’évaluer les progrès apportés par la « navigation ».

Une série de 300 prothèses Innex® non cimentées placées par le même opérateur (JLL) a été étudiée radiologiquement après 2 mois, avec un profil et une télogéométrie debout de face, pour mesurer le positionnement dans 2 plans. De face, l’axe des implants a été mesuré par rapport aux axes mécaniques du fémur (angle F) et du tibia (angle T). De profil, l’inclinaison de l’implant tibial (PDT) a été mesurée par rapport à l’axe proximal du tibia et l’inclinaison de l’implant fémoral (PDF) par rapport à l’axe du fémur distal. Il y avait 248 genu varum et 52 genu valgum avec une majorité de gonarthroses (238 cas et 44 reprises d’ostéotomies). L’âge était de 72 ± 8 ans.

Le résultat des mesures montrait un alignement hanche-genou-cheville (HKA) = 179,4 ± 2,4°, (173-186) dans une fourchette de ± 3° pour 87 % des cas, F = 90,1 ± 1,4° (87-95), à ± 3° pour 98,7 %, T = 89,3 ± 1,5° (85-94), à ± 3° pour 95,6 %, PDF = 88,6 ± 1,6° (84-93), à ± 3° pour 87 %, PDT = 87 ± 2° (81-93), à ± 3° pour 94 %. Les 4 coupes étaient dans une fourchette de ± 3 degrés pour 75 % des prothèses et ± 2 degrés pour 52 %. La durée opératoire pour la pose des implants a été de 68 ± 23 minutes et de 85 ± 23 minutes avec la fermeture comprise.

Chaque coupe a été faite avec une précision moyenne satisfaisante et un écart-type faible ce qui permet de relativiser la précision actuelle de la navigation sans vouloir remettre en question son apport bénéfique, tout en rassurant les opérateurs qui n’en disposent pas encore, d’autant que certaines erreurs isolées sont susceptibles de disparaître avec une meilleure utilisation des ancillaires.

Mots clés : Genou, prothèse totale du genou, chirurgie assistée par ordinateur.

ABSTRACT

Purpose of the study

Short-term functional results and long-term outcome in terms of stability and wear greatly depend on the precision of the bone cuts. We wanted to know whether conventional ancillaries are still competitive in terms of accuracy in comparison with computer-assisted navigation systems. A few comparative studies favor navigation, but have generally only included a small number of patients. We studied radiographically a prospective consecutive series of 300 total knee prostheses (Innex®, Zimmer) implanted with the conventional technique by the same operator.

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Material and methods

A view of the knee in the upright position and a short lateral view were obtained in all patients. In the AP view, implants were measured in comparison with the mechanical axis of the femur (F) and the tibia (T). On the lateral view, the prosthesis-tibial shaft angle (PT) was measured from the proximal portion of the tibial shaft and the prosthesis-femoral shaft angle (PF) from the distal portion of the femur. The same operator took all measurements using the same optimal conditions. The series included 178 women and 122 men (mean age, 72 ± 8 years) who presented genu varum (n = 248 knees) and genu valgum (n = 52 knees): degenerative disease (n = 238), polyarthritis (n = 4), hemophilic arthropathy (n = 3), necrosis (n = 3), revision of unicompartmental prosthesis (n = 8), and osteotomy (n = 44).

Results

The standard x-ray protocol was taken at 2 months in all patients. The mechanical axis (HKA) was 179.4 ± 2.4° (range, 173-186°) and was ± 3° in 87% of knees with no difference for varum and valgum. F was 90.1 ± 1.4° (87-95), with ±3° for 98.7%. T was 89.3 ± 1.5° (85-94) with ±3° for 95.6%. PF was 88.6 ± 1.6° (84-93) for 87%. PT was 87 ± 2° (81-93) with ±3° for 94%. The four cuts were within ±3° for 227 prostheses (77%), within ±2° for 156 (52%), and within ±1° for 56 (18%). Measurements taken again 1 year after implantation for 203 knees gave the same results. Operative time for implantation was 68 ± 23 min for implantation and 85 ± 23 min including complete closure (less than 60 min for 68 knees).

Discussion

The accuracy of each cut was satisfactory on average with a small standard deviation. Recent data in the literature show that the accuracy in our series is comparable with that obtained currently with navigation systems. In light of this experience, it can be seen that better precision can be achieved for each of the cuts.

Conclusion

The accuracy of conventional instrumentation systems is still comparable with that obtained with computer-assisted surgery. The purpose of this study was not to question the benefit of navigation, but to establish a basis upon which progress can be measured. The results enabled a more realistic comparison of the precision of navigation systems and also can be reassuring for operators still using conventional ancillaries.

Key words: Knee, total knee prosthesis, computer-assisted knee arthroplasty.

INTRODUCTION

The short-term results of total knee replacement in terms of function and long-term for wear depend to a large extent on the quality of the prosthesis placement and the precision of the bone cuts. Now that surgeons have computer-assisted techniques available for making these cuts, we deemed it important to evaluate the precision of the conventional techniques. A few comparative studies have been published [Saragaglia et al. [1], Jenny and Boeri [2], Stulberg et al. [3], Hart et al. [4], Sparmann et al. [5], Chauchan et al. [6]], concluding favorably on navigation, but they were generally based on small series and their conclusions cannot be applied to a given prosthesis and ancillary material. Can the ancillary systems currently in use still compete with this computer-assisted navigation in terms of precision? The aim of our study was not to question the beneficial contribution of navigation, nor its utility, but we should ask the question of the limits of the currently used ancillaries. We report a prospective and continuous series of 300 Innex® (Zimmer) total knee implants placed by a single operator (JLL). Implant placement was studied after 2 months for all cases (and after 1 year for 203 cases).

MATERIAL AND METHODS

The series of 300 implants included all the total knee replacements performed during the study period whatever the etiology, excluding hinge-type prostheses. There were 237 cases of gonarthrosis, four cases of rheumatoid arthritis, three cases of hemophilic arthropathy, three cases of necrosis, one case of Paget disease, eight replacements of unicompartmental prostheses, and 44 osteotomies. There were 246 genu varus and 54 genu valgus. There were 256 patients (22 bilateral cases; 179 females and 121 males) with a mean age of 72 ± 8 years (range, 26–88 years). The prosthesis used was the Innex® (Zimmer) model with a mobile tray, cementless, and preservation of the posterior cruciate ligament for 261 cases and the ultracongruent rotating model for 39 cases.

Bone cuts were made with a classic ancillary system using a cutting guide interlocked with a centromedullary stem for the femur and a cutting guide dependent on an extramedullary tibial alignment guide. The cuts were independent.

This purely radiographic study was based on an upright frontal gonometric view, with the feet parallel and the knees in complete extension with a constant distance between the source of x-rays and the plate; and a short lateral view, the knee flexed at 70°, taking into account the position of the implants in the frontal and sagittal planes. Rotation was not studied because a scanner was not available. Lines were drawn on x-rays placed on a horizontal x-ray film viewer, with the operator set up in optimal conditions, seated, with a fine pencil, a flat metal ruler, and a precise goniometer. The measurements were taken by the same operator (JLL) after each consultation, on a day-by-day basis, over 3 years. All patients were followed up 2 months after surgery and after 1 year 203 of them.

On the frontal views, we measured the HKA angle between the mechanical axes of the femur and tibia defined...
by the center of the four epiphyses of the limb, the distal femoral angle (or F angle) measured from the medial side between the line joining the distal part of the two condyles and the line joining the center of the femoral head and the center of the condyles, and the upper tibial angle (or T angle), corresponding to the angle between the metal tray and the axis of the tibia measured from the medial side (fig. 1). When the F angle was greater than 90°, we noted femoral valgus, and when it was less than 90°, we noted femoral varus. When the T angle was less than 90°, we noted tibial varus, and when it was greater than 90°, we noted tibial valgus. We looked for alignment of the hip, knee, and ankle based on an HKA angle of 180° and a balance between the femur and the tibia: F = T = 90°.

On the lateral view, the prosthesis-tibial shaft angle (PT) was measured from behind in relation to the tibial axis, represented by two points, one in the middle of the diaphysis, 20 cm from the line, the other in the middle of the metaphysis, just below the anterior tibial tuberosity. A slope inclined toward the back was expressed by a PT angle less than 90° (fig. 1). We planned to preserve a slight tibial tilt of 87° on these short films. The inclination of the prosthesis-femoral shaft angle (PF) was measured toward the back in relation to the distal femoral axis, represented by two points, one in the middle of the diaphysis 20 cm from the line and the other in the middle of the metaphysis, at the apex of the trochlea. The landmarks used to determine the implant axis (studs or anterior or posterior surfaces were independent of the rotation and the superposition of the condyles. The PF angle sought was 90° (fig. 1).

On the frontal preoperative views, we also measured the HKS angle between the mechanical axis of the femur already defined (HK) and the anatomical axis of the distal femur designated by a line joining the center of the condyles and the center of the diaphysis at 20 cm from the articulatory line (KS) (fig. 1). Measuring the HKS angle is highly important when a distal femoral cutting block with an intraosseous guide is used, since the ancillary must reproduce this angle so that the cut is perpendicular to the femur’s HK angle. The mean value of the HKS angle was 6 ± 2° (table 1), but there was great variability, ranging from 2° to 13°, meaning that this ancillary must be precisely adjusted.

Individual data were treated using Statview software. All the data measured were subjected to a descriptive analysis. The reliability of such routinely used radiological measurements has been proved for several years. In particular, the different measurements were taken twice for 20 knees, 4 months apart, and were evaluated once by a second operator, showing inter- and intraobserver reliability. Nonparametric correlations of all the measurements taken by two different operators were significant to 0.01, demonstrating very good interobserver reliability. The nonparametric correlations of all the measurements taken by a single operator 1 year apart were significant to 0.01, showing a very good intraobserver reliability.

Table I. – Measurements of the HKS angle for the 300 cases of the series.

<table>
<thead>
<tr>
<th>HKS</th>
<th>2°</th>
<th>3°</th>
<th>4°</th>
<th>5°</th>
<th>6°</th>
<th>7°</th>
<th>8°</th>
<th>9°</th>
<th>10°</th>
<th>11°</th>
<th>12°</th>
<th>13°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases (n)</td>
<td>1</td>
<td>10</td>
<td>32</td>
<td>61</td>
<td>91</td>
<td>51</td>
<td>33</td>
<td>8</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

FIG. 1. – a) Measurements of HKA, HKS, F, and T angles on knee x-ray with load. b) Measurement of the PF angle on lateral view between the implant and the distal femur axis (center of diaphysis and center of metaphysis at the apex of the trochlea). c) Measurement of the PT angle between the implant and the lateral tibia axis (center of diaphysis and center of metaphysis, just below the anterior tibial tuberosity).
RESULTS

Duration of surgery

The mean duration of surgery for the 300 operations was 85 ± 22 min (opening and closing included); 68 lasted less than 60 min. The duration of arthroplasty, corresponding to the duration of tourniquet placement, was 68 ± 23 min. The mean duration of surgery was 80 ± 19 min (range, 45-150 min) for the 225 knees operated on for the first time, with tourniquet application lasting 63 ± 21 min (range, 28-120 min).

Angle results

The angle results are summarized in table 2 and fig. 2.

The mechanical axis of the limb reflected by the mean postoperative HKA angle was 179.4 ± 2.4° (range, 174°-186°). The 246 varus knees were corrected from 171 ± 5° to 179.3 ± 2.2° and the 54 valgus knees were corrected from 186 ± 5° to 179.6 ± 2.6°; there was no difference between the results obtained in the two categories of knees. The mean values obtained for each cut were close to the values planned. For 227 out of 300 (75%) prostheses, the four cuts were located within a range of ± 3 degrees. For 156 out of 300 (52%), the four cuts were located within a range of ± 2 degrees, and for 56 out of 300 (18%), the four cuts fell within a range of ± 1 degree. The measurements were retaken after a delay of 1 year of 203 of these knees, with the same results.

The most significant cutting errors

For the HKA angle, we observed 14 excessively varus knees between 5 and 6 degrees; for F, two cuts in valgus of knees between 5 and 7 degrees and three valgus knees. The most significant cutting errors were retaken after a delay of 1 year of 203 of these knees, with the same results.

For PF, there were 15 femoral implants that were excessively varus, which were the greatest errors. For PT, there were seven errors by 5 and 6°; four excessive tilts and three inversed tilts. We sought to determine whether these frontal cutting errors were compensated or on the other hand were accumulated. When F was excessively varus, the tibial cut accentuated the varus 24 times, whereas when it compensated it only three times. When F was excessively valgus, T compensated the valgus 16 times and increased it ten times.

DISCUSSION

Cutting precision

Cutting precision is an obsession for most knee surgeons. The objection is often raised that it has not been proven that the precision of the cuts has an incidence on the results. However, many studies have demonstrated that the long-term results depend to a large extent on proper position of the implants and on proper ligament balance. A defective frontal axis promotes loosening [Hsu et al. [7], Jeffery et al. [8], Feng et al. [9], Rinopapoli et al. [10], Ritter et al. [11]], particularly in terms of tibia varus, which encourages polyethylene wear [Huang et al. [12], Matsuda et al. [13]], as does sagittal malposition [Wasielewski et al. [14]]. Ligament balance is influenced by the sagittal positioning of the tibial implant [Singerman et al. [15], Whiteside and Amador [16]] or migration of the implant [Hofmann et al. [17]], malposition frequency varies between 8% and 30% according to Ritter et al. [11]. Krugluger et al. [18], Reed and Gollish [19], Teter et al. [20][art1-bib21][21], but it has not yet been defined where malposition starts, hence the notion of angle ranges attributed to each angle measured by Jenny and Boeri [2].

Measurement precision

The precision of the measurements taken depends greatly on the quality of the x-rays used. Like Duparc and Massare [22], Cooke et al. [23], Oswald et al. [24], Patel et al. [25], Swanson et al. [26], Prakash et al. [27], we chose to use an upright frontal view with the patient standing on both feet to facilitate the procedure even though it limits the ligament component of the deformation. Several studies have dem-

Table II. – Measurements of the angles indicating the frontal and lateral position of implants, with the percentage in a range of 3°, 2°, and 1° on one side or the other of the ideal position.

<table>
<thead>
<tr>
<th>n=300</th>
<th>Degrees</th>
<th>Percentage of arthroplasties precise to ± 3°</th>
<th>Percentage of arthroplasties precise to ± 2°</th>
<th>Percentage of arthroplasties precise to ± 1°</th>
</tr>
</thead>
<tbody>
<tr>
<td>F angle</td>
<td>90.1 ± 1.4 (87-95)</td>
<td>98.7</td>
<td>94.3</td>
<td>71.3</td>
</tr>
<tr>
<td>PF angle</td>
<td>88.6 ± 1.6 (84-94)</td>
<td>87</td>
<td>73</td>
<td>59</td>
</tr>
<tr>
<td>T angle</td>
<td>89.3 ± 1.5 (85-94)</td>
<td>95.6</td>
<td>86.3</td>
<td>62.3</td>
</tr>
<tr>
<td>PT angle</td>
<td>87.3 ± 2 (81-93)</td>
<td>94</td>
<td>73.3</td>
<td>57</td>
</tr>
<tr>
<td>HKA angle</td>
<td>179.4 ± 2.3 (173-186)</td>
<td>87</td>
<td>72.3</td>
<td>46.6</td>
</tr>
</tbody>
</table>
In practice, it is particularly important that the instrumentation allow the surgeon to orient the cutting block on the nail by the exact HKS angle value measured. Ancillary systems are available that allow one to place the template within 1 degree of precision (range, 3°–9°). Not all ancillary instruments are this precise and most have templates oriented at 2° intervals, as for the Innex® prosthesis (4°, 6°, and 8°). We also have a small corrector template adding or subtracting 2°, which is placed on the fixation pins so as to adapt to extreme situations (table 1 shows that femoral curves exist with aberrant HKS angles under 4° and above 10°). We should be able to correct in either direction by 1° when the HKS value is an odd numbered value. This can be done by turning the cutting template around the most external fixation pin to modify the thickness of the cut by 1 mm on the internal side and fixing it with another pin (To be even more precise, the surgeon should have a small 1° corrector template). It is also possible to deliberately place one of the two even-numbered templates that is nearest the HKS angle, by choosing either 1 degree varus or 1 degree valgus.

The lateral distal femoral cut

The lateral distal femoral curve is sometimes very pronounced and the shaft does not correspond to the metaphysis axis, which can be problematic when centromedullary nails are to be used [Reed and Gollish [19], Teter et al. [21], Laskin [35]]. The centromedullary nail in this case requires making a distal cut over in flexion [Stulberg et al. [3], Sparmann et al. [5], Mahaluxmivala et al. [28]] and it would be necessary to introduce it further in front to compensate. When a navigation system is used that integrates the femoral head and the center of the knee location is also available, a perfectly perpendicular cut of the femur can be made. In both techniques, there is a risk that the anterior cut cuts into the femoral cortex when attempting to compensate the curve. A compromise is possible between the two cuts: placing the implant in a slight position of relative flexion (fig. 3). The method used to measure the PF on the x-rays therefore erroneously concluded, in these cases, that the implant was placed excessively in flexion, by 3° to 5° less than the usual 90°, which severely jeopardized the implantation, while we consider that these implants were properly implanted in relation to the distal femur anatomy. Rather than using the PF angle measurement, we believe it would be preferable to measure the alignment of the anterior cortex of the femur and the axis of the implant.

The lateral proximal tibial cut

This cut was nearly as precise in the frontal position as in the lateral with classic instrumentation, as for Teter et al. [20]. The extramedullary tibial alignment guide used includes an automatic 84° inclination of the cutting template in relation to the stem and therefore provides a 6° backward inclined cut when it is placed parallel to the axis joining the middle of the knee and the middle of the ankle.
FIG. 2. – Frequency distribution of femoral and tibial implant position for 300 total knee replacements. a) Frontal alignment of limb. b) Lateral PF angle. c) Angle de l’implant tibial de face. d) Frontal PF angle. e) Frontal PT angle.
However, bringing the stem nearer or farther away from the ankle using a curser system can also be implemented, remembering that 7 mm corresponds to one degree of inclination (for a mean tibia length of 36 cm). The inclination can also be traced on the template in relation to the anatomical tibia, using a pin attached to the template. Using a 6° slope integrated into the extraosseous instrument extending from the knee to the ankle has shown, on average, a PT angle ranging from 87° when measurements are taken on short films that do not include the upper third of the tibia and when the entire sagittal curve is taken into account; the precision of this cut has been very good, as we have seen.

A few cases had a slope that was 5° more than expected, which seems a bit excessive, but the error is not very important in that some authors consider that the implant’s tilt can reproduce the anatomic tilt when the PCL is preserved (before surgery, 130 knees had a slope of 82° or more). The future will show whether these small differences in tibial inclination will cause surface wear or ligament distension. Sparmann et al. [5] found no differences for tibial tilt in the two series of 120 knees operated on with and without computer-assisted navigation, and they suggest that the precision is sufficient when judged visually and manually.

The frontal tibial cut

The frontal tibial cut was specified with the extramedullary tibial alignment guide. Laskin [35] emphasized that identifying the mid-malleolar point could lead to a slight imprecision, because it did not always correspond to the center of the talus. The alignment guide that we used includes a curser system that allows a mediolateral adjustment in relation to the mid-malleolar point. We used a second system to check the position of the tibial cutting jig, once it was fixed with two pins, with a complementary verification by a stem in relation to the ankle. In addition, the thickness of the cut bone can be measured with a caliper ruler, which should match the value from radiological planning. Errors have been rare; nevertheless, the frontal tibial cut was made nine times with a 6° excessive varus, which was the most regrettable error, especially when there was not a slight compensating valgus in the femur, and even more so when there was slight varus, which worsened the consequences of the error.

Comparing precision with and without navigation

Computer-assisted navigation is currently in full expansion, with several comparative studies now available that tend to show that the cutting precision has been improved. Four teams have reported results obtained with the OrthoPilot® system and the Search® prosthesis (Aesculap, Tuttingen, Germany). With a prospective and randomized study investigating two series of 25 knees, Saragaglia et al. [1] have shown that the precision on the overall axis has improved with computer-assisted navigation, since the number of centered knees at 180° has gone from 75% to 84%, but this result was not significant. The mean values obtained for the four angles with a navigation system were comparable to ours. The authors indicated ranges for PF, with a precision of ± 1°, had progressed from 41% to 76% with the navigation system, a significant result, whereas we reached only 57% (however, we have just explained that our precision was certain underevaluated for this criterion). Jenny and Boeri [2] published a randomized study of two series of 25 cases. They introduced the notion of optimal implantation with very rigorous criteria, since the four cuts had to be within a range of ± 3° of the ideal. Without navigation, 15 cases out of 50 (30% of cases) responded to the criteria, versus 33 cases out of 50 (60%) with navigation. In a fourth study, Hart et al. [4] compared two series of 60 knees (type of prosthesis not specified): they noted few differences with and without navigation for the mean values, except for PF; they did not provide the angle ranges. Sparmann et al. [5] investigated two series of 120 knees (Duracon Condylar® prosthesis) replaced with and without computer-assisted navigation (Stryker Knee Navigation System® from Stryker Howmedica Osteonics, Allendale, New Jersey, USA) with a significant improvement in all cuts, since the precision obtained for HKA, F, and PF angles was ± 3° in 100% of cases, but the PF and T angles were less precise, with only 80% and 82%, respectively, as in our own study where PF was the least precise. For the PF angles, the authors only retained the cases where a long lateral x-ray including the hip was available (73 and 86 cases); in the group in which navigation was used, 80% of the knees were ± 3°, whereas in the manual group, there were only 22%. For Chauchan et al. [6], who compared two series of 35 cases operated on with the same system, the improvement with navigation system was not significant for PF, but it was for all the other cuts; however, the values were not reported.
Computer-assisted navigation is again a relatively complex and time-consuming technique to set up, but its disadvantages are relative because they subside with experience and will be reduced as the technology is perfected. Some systems that required preoperative CT scans for the acquisition of morphological data no longer do so today, such as the Navitrac® Navigation System (Zimmer) [Nizard et al. [37]] and the BrainLAB® system [Bathis et al. [38]], and the data are acquired during the operation. With navigation, x-rays could theoretically be eliminated. With the classic technique that uses a centromedullary guide, only a frontal knee x-ray measurement is required to measure the HKS, F, and T angles (the measurements taken on the lateral x-ray are not indispensable for the operative technique itself).

Duration of surgery

The increase in the duration of surgery related to the navigation system is a very relative disadvantage that is largely compensated by the quality of the implantation if it is indeed significantly improved, but it should not become responsible for complications attributable to an excessive tourniquet time or possible infections. The additional operation time related to the navigation system can only decrease with the method’s progress. This time has been variable, ranging from 13 to 32 min, keeping in mind that all operators of the series were reported. For Nizard et al. [37], this duration was 120 ± 34 min. For Saragaglia et al. [28], a series of 673 prostheses showed that the positioning of the implants was independent of the level of experience of the operator, since the measurements were comparable (except for a standard deviation slightly more spread out for young operators). This reflects our experience with our young collaborators. This supports the objective of this investigation, which will undoubtedly continue to be made in computer-assisted surgery and this should reassure, temporarily perhaps, surgeons who do not yet have access to these tools.

Surgeon’s experience

This is a single-operator series; it would be tempting to argue that the surgeon’s experience could contribute to improving the performance of the ancillary system, but the study of Mahaluxmivala et al. [28], a series of 673 prostheses showed that the positioning of the implants was independent of the level of experience of the operator, since the measurements were comparable (except for a standard deviation slightly more spread out for young operators). This reflects our experience with our young collaborators. This supports the objective of this investigation, which sought to prove unequivocally the reliability of a technique independently of experience.

The precision of the bone cuts with a traditional ancillary has therefore been satisfactory and it can again be compared favorably with today’s navigation methods, especially since on 300 knees, only 225 were on nonoperated knees, whereas all the series reported in the literature excluded these more difficult cases. The precision obtained is all the more valuable.

CONCLUSION

The precision of bone cuts obtained using a traditional ancillary system is satisfactory, particularly since it can still be perfected at each step of the procedure. Today it can still compete with computer-assisted navigation systems. This series could serve as a basis for evaluating the progress that will undoubtedly continue to be made in computer-assisted surgery and this should reassure, temporarily perhaps, surgeons who do not yet have access to these tools.

References