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ORIGINAL STUDY

Influence of patellar subluxation on ligament balancing in total knee arthroplasty through a subvastus approach. An in vivo study

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Post-operative joint stability and ligament balance are crucial factors in the longevity of the prosthesis after total knee arthroplasty (TKA). The influence of patellar position on the balance of the knee is controversial. We studied the influence of patellar subluxation on tibiofemoral pressure distribution i*n vivo*, in 32 knees undergoing TKA through a subvastus approach. We used the e-LIBRA Dynamic Knee Balancing System® (Synvasive Technology, El Dorado Hills, CA, USA). This is a device that measures the pressures in the medial and lateral compartment independently. After balancing the knee in flexion with the patella in place, we demonstrated a significant rise in pressure in the medial compartment with subluxation of the patella ($p < 0.0001$). Our findings give a new insight on the role of the patellar position while balancing a total knee arthroplasty. Surgeons should be aware of this effect when choosing their surgical technique for this operative procedure.

Keywords : total knee arthroplasty ; ligament balancing ; patellar position ; in vivo.

INTRODUCTION

Total knee arthroplasty (TKA) has become a routine intervention with very high success rate for the treatment of primary and secondary osteoarthritis of the knee (*5,17,19*). Post-operative joint instability is a common cause of dysfunction, leading to premature poly-ethylene wear and aseptic loosening with possible need for revision surgery (*10,12,16,20*).

Alignment and ligament balance are surgically controllable factors of the stability following total knee replacement. Over the past decade, we have seen the introduction of multiple systems to improve the accuracy of alignment and balance such as navigation systems, ligament tensioners and pressure-measuring devices (*8,14,21,25*). The influence of the patellar position on tibiofemoral pressure distribution and ligament balance has only been described in cadaver experiments (*4,7,13*). We used the e-LIBRA Dynamic Knee Balancing System® (Synvasive Technology, El Dorado Hills, CA, USA) to measure the tibiofemoral pressure distribution intra-operatively.

The aim of this study was to determine the influence of patella subluxation on the tibiofemoral pressure distribution after having balanced the flexion gap with the patella in place.

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MATERIAL AND METHODS

Between February and August 2009, 36 consecutive patients underwent unilateral TKA with the e-LIBRA® technique. All procedures were performed by one surgeon (LB).

There were 22 women and 14 men ; 25 left knees and 11 right knees ; 35 had osteoarthritis and 1 had osteonecrosis of the lateral femoral condyle. Thirty-one knees had a varus alignment and 5 knees had a valgus alignment. All deformities were manually correctable under anaesthesia. Mean age was 68 years (range : 41-84) ; mean body mass index was 29.8 (range : 18.2-48.4).

A Vanguard Cruciate Retaining (CR)® prosthesis (Biomet,Warsaw, IN, USA) was used in 35 procedures ; a Vanguard Posterior Stabilised (PS)® design was used in one patient because of posterior cruciate ligament (PCL) insufficiency.

All patients had the same operative technique without a tourniquet. We used a standard medial parapatellar skin incision and subvastus approach. The medial patellofemoral ligament was incised at the supero-medial pole of the patella. The medial retinacular structures and the synovium and capsule were separated by blunt dissection. The retinaculum was then incised at the parapatellar level and the arthrotomy was made just anterior to the medial collateral ligament (fig 1). All meniscal remnants and osteophytes were removed.

A proximal tibial cut at 8 mm was performed perpendicular to the long axis of the tibia with 3° posterior slope. A 9mm distal femoral resection was performed with 7° of valgus. The femoral component of the e-LIBRA® was mounted on the femur (fig 2) in the appropriate position. This component has a mobile element (fig 3) underneath the lateral condyle to adjust for external rotation. The e-LIBRA® sensor (fig 4) and tibial insert were introduced to tension the collateral ligaments. The e-LIBRA® is a an electronic device with pressure sensors on the medial and lateral side. These sensors measure the pressure in the medial and lateral compartment independently and transmit these to a display. We always started with a 10mm insert. If insufficient pressure was detected by the e-LIBRA® sensor, a thicker insert was used.

The patella was reduced and the knee was flexed to 90°. A standardized balancing technique was used : the hip was flexed to lift the weight of the femur, a drape was used as a sling to cradle under the Achilles tendon to prevent varus/valgus influence on the collateral ligaments (Fig 5). According to the noted compartment pressures the external rotation of the e-LIBRA® femoral component was adjusted until there was an equal pressure laterally and medially.

After balancing the knee, the patella was subluxed again and the pressure distribution was measured again. The differences between compartment pressures medially and laterally were noted.

Two drillholes were made through the femoral component to mark the external rotation (fig 2). These drillholes are adapted to be used with the "4 in 1" femoral cutting block of the Vanguard® knee system. After completing the femoral cuts, the knee was brought into extension. Balancing in extension was done with spacer blocks as there is no instrumentation available yet in the e-LIBRA® system to measure the tibiofemoral pressure in extension. In case of imbalance in extension, the valgus angle of the distal femoral cut was adapted and a 1 mm recut was made. We resurfaced all patellas and all the components were cemented in one stage with vacuum-mixed Refobacine® Plus Bone Cement (Biomet Warsaw, IN, USA).

The data in our study consist of ordinal variables. This balancing sytem did not give us exact pressures, it gave us a number. The higher the number displayed, the higher the actual pressure. The difference in pressure between the medial and lateral compartment, before and after subluxation of the patella (table I) was used for statistical analysis. The Wilcoxon signed rank test was used for statistical analysis. We used this test because the data consists of ordinal variables.

RESULTS

We were unable to balance 3 knees (marked with $^{+}$) out of the 36 in the series (table I). These knees were tighter laterally than medially before balancing. Even with proper resection of all the osteophytes there was more pressure on the lateral side. The design of the e-LIBRA® system does not allow to put the femoral component in internal rotation. One of those three knees had a history of an open resection of a Baker's cyst and had, possibly as a consequence, posterolateral scarring and tightness. The second knee was well aligned and the third had osteonecrosis of the lateral femoral condyle. In these 3 knees a release was performed and for that reason they were excluded.

In a fourth knee (marked with *) we had to implant a PS-prosthesis (table I). This patient had a

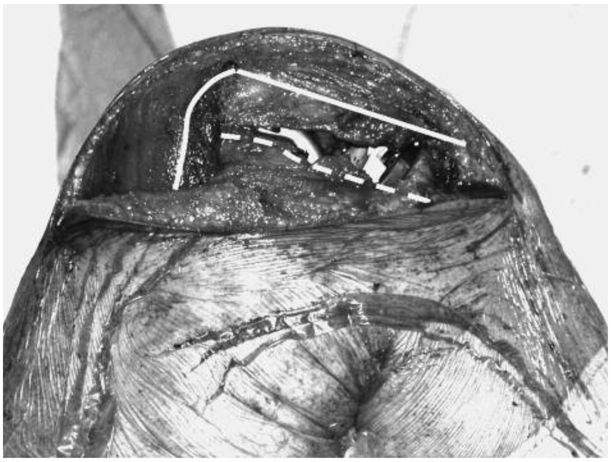

Fig 1. — Lateral view of the knee ; white line : level of retinacular incision ; white striped line : level of arthrotomy.

Fig 2. — Front view of the knee with the femoral e-LIBRA® component in place ; white circles : drillholes to mark the external rotation.

Fig 3. — Posterior view of the femoral e-LIBRA® component.

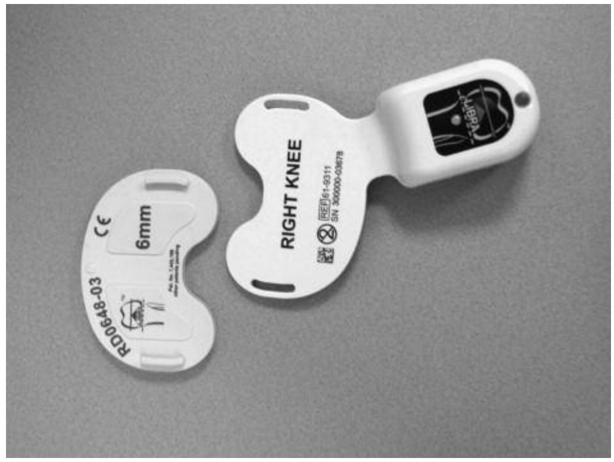

Fig 4. — e-LIBRa® sensor and a tibial insert.

Fig 5. — Lateral view of balancing method.

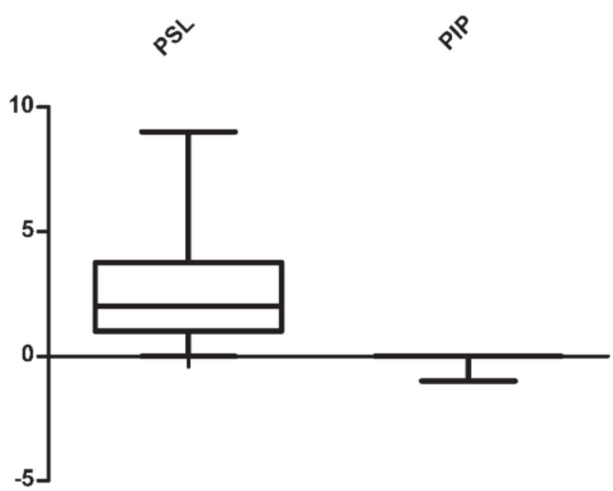

Fig 6. — Differences in pressure – in arbitrary units – between medial and lateral compartment with PSL (Patella Subluxed) and PIP (Patella in place) in Box-plot with 95% CI.

Table I. — Pressure measured before (Patella In Place) and after (Patella SubLuxed) subluxation of the patella in the medial and lateral comportment independently.

PIP M/L	PSL M/L	Relative shift to medial side
2/2	2/1	1
7/7	7/5	2
3/3	4/2	2
5/5	7/3	4
10/11	10/5	6
6/6	10/5	5
7/7	9/5	4
5/5	5/4	1
5/5	5/3	2
11/11	16/9	7
2/2	3/2	1
5/5	7/5	2
5/5	5/4	1
3/3	4/2	2
3/3	4/2	2
3/3	4/3	1
4/4	3/2	1
5/6	7/3	5
1/1	3/0	3
5/5	8/5	3
1/1	4/0	4
1/1	4/1	3
4/4	5/2	3
6/6	7/6	1
4/4	2/0	2
3/3	3/2	1
3/3	4/2	2
5/5	6/6	0
3/3	4/3	1
4/4	9/0	9
2/2	4/3	1
2/2	3/1	2
$0/4^{+}$	$0/2^{+}$	2^{+}
$0/6^{+}$	$0/4^{+}$	2^{+}
$3/3^{+}$	$3/3^{+}$	0^{+}
0/9	N/A*	N/A*

history of an anterior tibial plateau fracture with an anterior downslope of the tibia as a consequence. After the tibial cut was made, the PCL was insufficient and a PS implant was deemed to be necessary. The measurements in this knee were not used for statistical analysis.

First we calculated the difference in pressure between the medial and the lateral compartment before and after subluxation of the patella. There was no statistical difference in pressure with the patella in place (PIP) ($p = 0.35$). With the patella in the subluxed (PSL) position there was a significant difference between the pressure in the medial and the lateral compartment ($p < 0.0001$) (fig 6). There was a shift of pressure towards the medial side (mean 2.63 ranking points ; 95% CI : 1.90-3.35) when the patella was subluxed.

Secondly we analysed the effect of patellar subluxation on the medial and lateral compartment separately. In the medial compartment there was a significant increase in the pressure ($p = 0.0001$) of 1.38 ranking points (95% CI 0.81-1.95).

On the lateral side there was a significant lowering of the pressure ($p < 0.0001$) of 1.28 ranking points (95% CI : -1.81 to -0.75).

DISCUSSION

Creating well balanced flexion and extension gaps is a key step in total knee replacement surgery. There are four commonly used techniques to establish proper rotational alignment of the femoral component and balancing the knee in flexion. The first three techniques rely on fixed bony landmarks : alignment perpendicular to the anteroposterior axis (so-called Whiteside's line) (*1,26*) ; 3° of external rotation off the posterior femoral condyles (*11*) ; parallel to the transepicondylar axis (*2,15*). The fourth technique is based on ligament tension : positioning of the femoral component is referenced to the cut tibial surface with the two collateral ligaments under equal tension (so-called tensioned gap method) (*23*). The transepicondylar axis has been shown to best approximate the normal flexion-extension axis of the knee (*3*).

There is an ongoing debate about which technique best approximates this axis. Hanada *et al* (*9*) advised to use Whiteside's line rather than the tensioned-gap method because the collateral ligament is more lax laterally (*24*). They described a varus malalignment in flexion when using a tensioned gap method in cadaveric knees. Siston *et al* (*22*) described a high variability in rotational alignment within all different techniques, with no technique being superior in their cadaveric study. They described Whitesides's line as being the most variable one with a standard deviation of 7.6° from the reference transepicondylar axis. Fehring (6) warned against the use of the posterior condyles as a fixed bony landmark in his *in vivo* study. When using 3° of external rotation routinely, 44% of the patients would have at least 3° error in rotation. Yau *et al* (28) advised to use a tensioned gap method in balancing the knee in flexion. In their *in vivo* study, this technique had the least variability and the lowest percentage of surgical outliers. Twenty percent of knees had a rotational error of more than 5° from the reference trans-epicondylar axis. In comparison, Whiteside's line had 60% outliers, the posterior condylar line had 72% outliers and the transepicondylar axis had 56% outliers. These differences were found to be significant. In our study we used a tensioned gap technique because it has been shown *in vivo* to have the lowest variability and it is less surgeon dependent in comparison with other techniques.

Until recently the effect of the patellar position in balancing the knee in flexion has been ignored. For the use of most ligament tensioners, the patella has to be everted or subluxed. Only a few cadaveric experiments have been published (4,7,13). To our knowledge this is the first *in vivo* study on this subject. We demonstrated that after subluxating the patella, forces shift towards the medial compartment and pressure rises medially and decreases laterally. With patella subluxation the muscle-patella-patellar tendon unit slides laterally and posteriorly to the flexion-extension axis ; in the coronal plane, the load shifts towards the medial side and the lateral side relaxes.

These findings are in contrast to the cadaveric experiments of Crottet *et al* (4) and Luring *et al* (13). They described a shift towards the lateral compartment when everting (4,13) or subluxating (13) the patella in a human cadaver. We did not measure the effect of patellar eversion because patellar eversion was not possible with our surgical approach. A possible explanation is that, when everting the patella, the muscle-patella-patellar tendon unit remains anterior to the flexion-extension axis in the coronal plane, thereby creating a lateral shift.

Luring *et al* (13) showed that there was less shift towards the lateral side when subluxating the patella than when everting it. The same reasoning can be followed : because of the rigidity of the cadaveric tissue the muscle-patella-patellar tendon unit does not slide posteriorly to the flexion-extension axis when subluxating the patella, creating a lateral shift. The shift is bigger in eversion because in eversion the muscle-patella-patellar tendon unit stays more anterior than when subluxating, creating a larger effect. Also the approach used seemed to influence the effect with a lesser effect for the subvastus compared to the medial parapatellar approach.

In our study the PCL was intact during the measurements. We do not know if this was the case in the previous cadaveric studies. The combined effect of our approach, subluxating the patella, the persistence of the PCL and living human tissue are probably the main reasons for our 'diverging' (with regard to the cadaveric studies) findings.

We balanced the flexion gap of our knees with the patella in place. In most other balancing techniques, this is done with the patella everted or subluxed. This would, based on our results, create a small lateral tightness/ medial laxity when subsequently reducing the patella from its subluxed position after balancing. This leads to a 'minor' imbalance in flexion and theoretically leads to lesser outcome and longevity because it is widely accepted that a correct soft tissue balance in TKA will reduce polyethylene wear and optimise the longevity of the prosthesis (18,21,27). Long term follow-up studies are needed to validate this hypothesis.

A weakness of this study is the relatively small size of the study group (32 patients) and the fact that it was a one-surgeon series. Despite the small sample size, the shift in pressure was present in all knees studied and the measured effect was highly significant. Furthermore the previous cadaveric studies had an even smaller sample size between 6 and 15 specimens. Another weak point is that we only studied the effect of patellar subluxation in 90° flexion. The reason is that there is no instrumentation available yet in the e-LIBRA® system to measure the tibiofemoral pressure in extension, or 30° and 60° of flexion with the patella in place.

CONCLUSION

Patellar position plays an important role in fine tuning the balance of a TKA in flexion. Changing the position of the patella after balancing the knee in flexion significantly changes the mediolateral balance of the TKA. Our findings are in contrast with those of previous cadaveric experiments. In our opinion it is a major advantage to have the patella in its anatomical position while balancing the knee. We suggest that balancing the flexion gap should be done with the patella in its anatomical position to achieve a correct mediolateral balance. In our view it is very important that surgeons are aware of this effect when choosing their surgical technique.

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