A COMPARATIVE BIOMECHANICAL STUDY OF THE STRENGTH OF THE BONY PATELLA FOLLOWING DOME CUT OR UNIPLANAR CUT IN TOTAL KNEE ARTHROPLASTY

O. SCHWARTZ, M. LEVIN, A. ROTEM, D. G. MENDES

This study was designed to investigate whether there is a difference in the strength of the bony patella following preparation either with a dome configuration or with a regular uniplanar cut in total knee arthroplasty.

For each test 4 cadaveric patellae were used. Two of the 4 patellae were prepared with a regular uniplanar cut and 2 were prepared into a dome shape with a circumferential wall, using a concave reamer. The thickness of each patella after preparation was 15 mm. The tests were performed using an impact drop weight apparatus.

In the first two tests, which tested the resistance of the patella to tensile force and evaluated the strength of the patella by impact load while under tension, the soft tissues were torn, with no harm to the bony patella. In the third test, which evaluated the resistance of the patella without tension against impact load, the force required to fracture the dome-shaped patella was greater than for the traditional uniplanar cut (500 Kg vs 350 Kg).

Dome shape with circumferential wall preparations of the bony patella in total knee arthroplasty were stronger in resisting external impact than the conventional uniplanar cut patella. This established the rationale for our use of the dome-shaped patella implant with a concave undersurface.

Keywords : patellar implant ; biomechanics ; dome-shaped ; patella.

Mots-clés : prothèse rotulienne ; biomécanique ; dôme ; rotule.

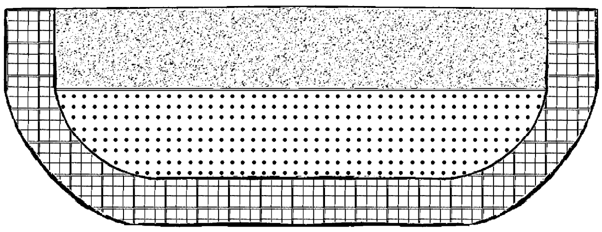

Fig. 1. — Uniplanar cut of patella

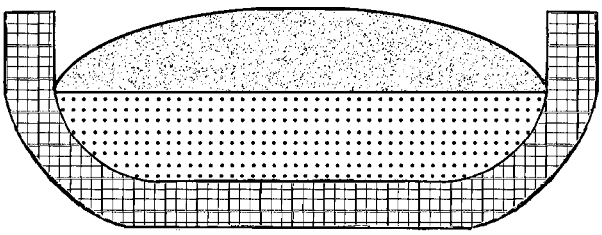

Fig. 2. — Dome-shaped cut of patella

Schematic diagrams representing the density of three different areas of the bony patella following resection of the subchondral bone. Note the preservation of the circumferential dense bone (A. soft cancellous bone. B. cancellous bone. C. dense circumferential wall).

INTRODUCTION

Since 1972 the bony patellar cut for patella resurfacing in total knee arthroplasty has been

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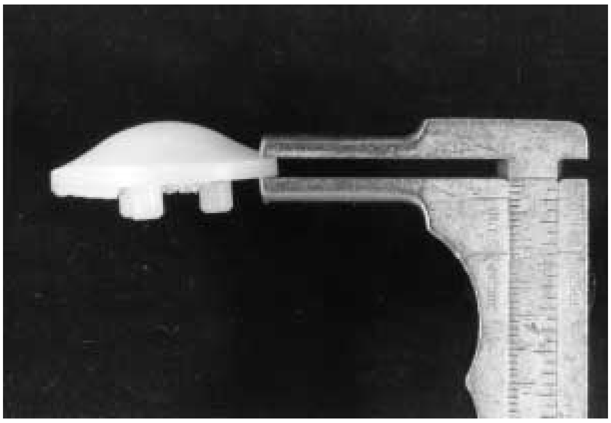

Fig. 3. — Conventional patellar button . Note the deficient thickness at the periphery.

performed with a frontal planar cut (fig. 1), that was resurfaced with a patellar “button” (fig. 3).

The main disadvantage of this technique is that it does not provide for adequate thickness of polyethylene patellar implants at the peripheral contact areas (3). This leads to several modes of failure such as deformation and fracture (4), loosening (1) and wear (2).

A new surgical technique, which was designed to address this issue, was developed in our center and implemented clinically.

The method creates a dome-shaped configuration with a circumferential wall to the bony patella (fig. 2). This provides for an inset position of the implant and adequate space for a uniformly 8-mm thick dome-shaped patellar implant with a concave undersurface (fig. 4).

The purpose of this study was to investigate whether there is a difference in the strength of the bony patella between the two methods of preparation.

For that purpose, biomechanical studies comparing the tensile and compressive yield stress of the patella, following the two methods of preparation were performed.

These studies followed a histomorphometry study of the structure of the patella [Jochanan H. Boss, Sorin Head, Edmond Sabo and David G. Mendes. Unpublished data 1998.], which distinguished the circumferential dense wall of the entire patella and the cancellous structure of its middle portion.

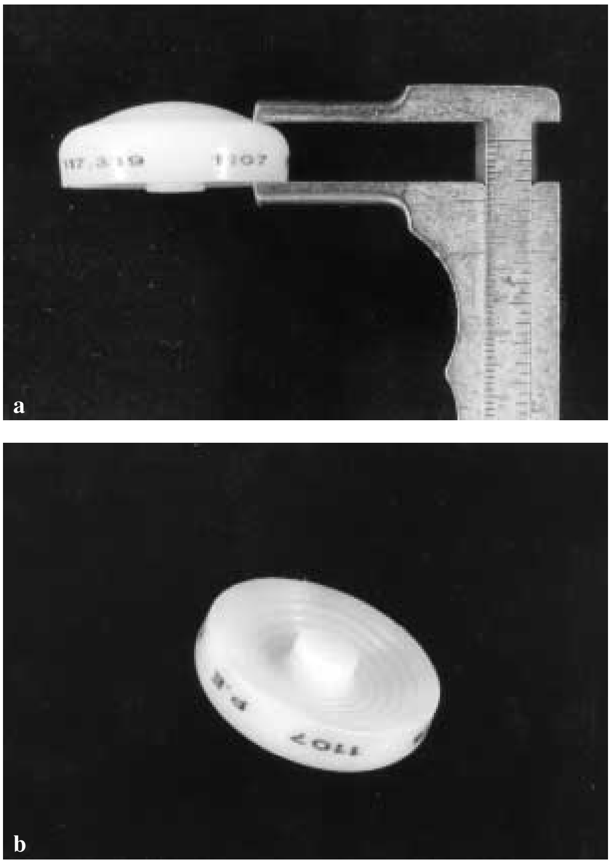

Fig. 4. — Our patella. **a.** Note the thickness at the periphery. **b.** Note the concave under-surface.

MATERIALS AND METHODS

Cadaveric patellae of middle-age road accidents victims with similar bone quality were used and kept in a conserving liquid for several weeks following harvesting. Half of the patellae were cut with the traditional uniplanar cut and half were reamed into a dome shape with 2-mm thick circumferential wall.

Following preparation patellae with the uniplanar cut were 15 mm thick. The dome-shaped patellae with the circumferential wall were 15 mm thick at the apex.

Three physiological patterns of failure were tested :

1. Tensile yield stress : this was done by applying tensile force to the quadriceps tendon and patellar ligament. Four specimens were used for each group.

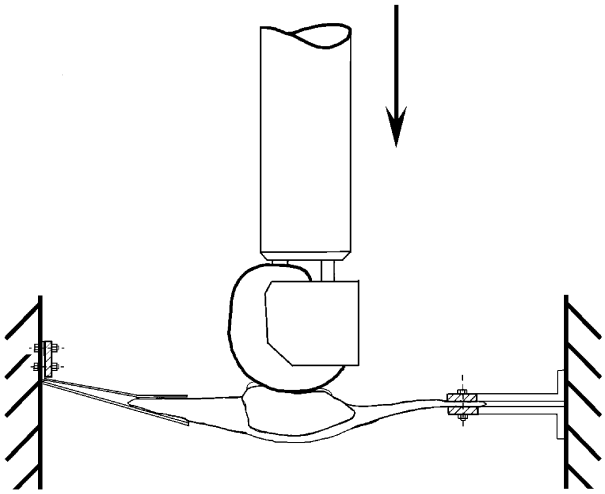

Fig. 5. — Description of the first test

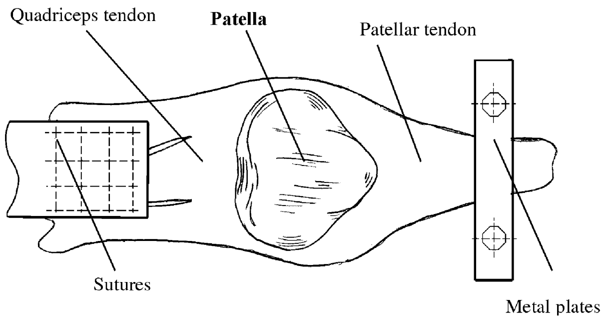

Fig. 6. — The attachments of the quadriceps and patellar tendons in tests 1 and 2. The quadriceps tendon was sewn to a synthetic band and the patellar ligament and tibial tuberosity were fixed between two metal plates.

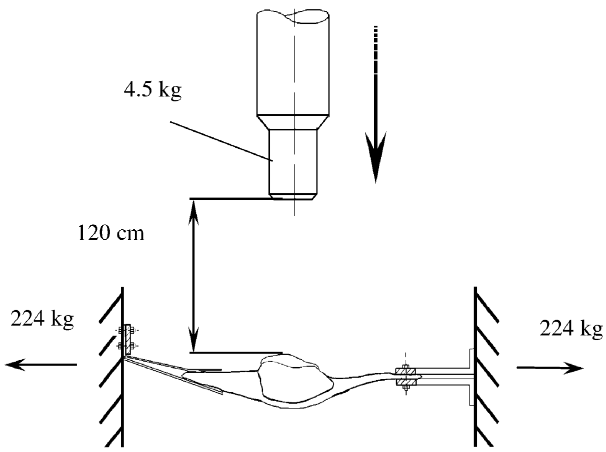

Fig. 7. — Description of the second test

The specimens were placed appropriately in an impact drop weight apparatus (IDWA). .

The tendons were tightened by sewing. The quadriceps tendon was sewn to a synthetic band and the patellar ligament and tibial tuberosity were fixed between two metal plates. The system was placed under tension which was gradually increased by applying a compressive force on the patella with the trochlear articulating surface of a femoral component (fig. 5).

2. Tensile stress combined with impact load : in this test the specimens were attached to the impact drop weight apparatus. Four specimens were used, two of each type. The patellar ligament and the quadriceps tendon were prepared in a manner similar to test 1 (fig. 6). Tension of 224 Kg. was applied to the soft tissue in opposing directions and a weight of 4.5 Kg was dropped from 120 cm on the bony patella and hit the patella strongly from its inside aspect (fig. 7).
3. Compression stress by impact load : in this test the compression strength of the bony patella was evaluated by an impact on its anterior aspect.

   Four specimens were used, two of each type. The patellae were placed in a metallic device and a 4.5 kg weight was dropped from 100 cm height on the anterior surface of the patella (fig. 8).

RESULTS

In the first test, tensile forces were applied on each side of the patella through the quadriceps and patellar ligaments. The patellar ligament and its tibial tuberosity attachment were torn when maximal force reached on average 157 kg.

In this situation the force that was applied on the patella in opposite directions calculated by the angle between the two vectors was 174 kg. This force did not cause any harm to the bony structure of either type (fig. 9).

In the second test a 4.5 kg weight was dropped from 120 cm height onto the bony patella while under tension through its ligaments. In all specimens the soft tissue, ligament and tendon were torn, with no harm to the bony structure of either type. The average forces at which soft tissues were torn, were160 kg in the uniplanar cut patellae and 270 kg in the dome-shaped patellae (fig. 10).

In the third test, when a 4.5 kg weight was dropped from 100 cm height onto the anterior

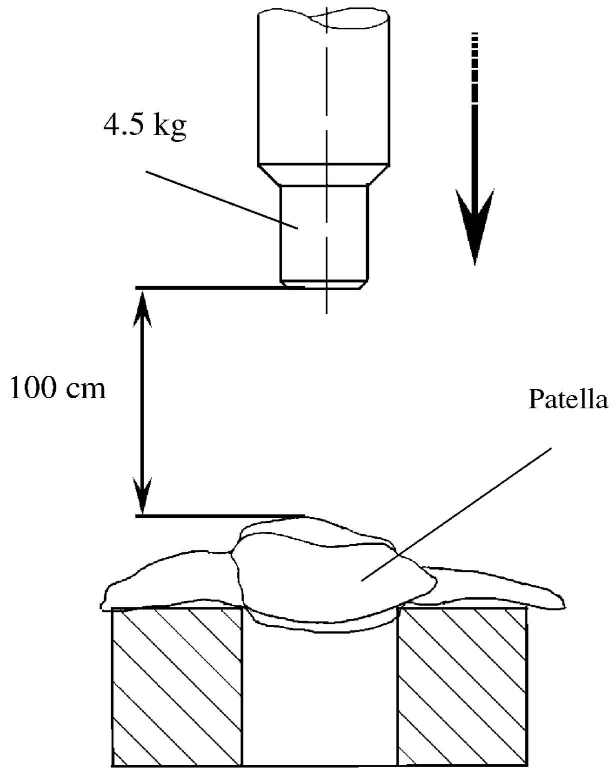

Fig. 8. — Description of the third test

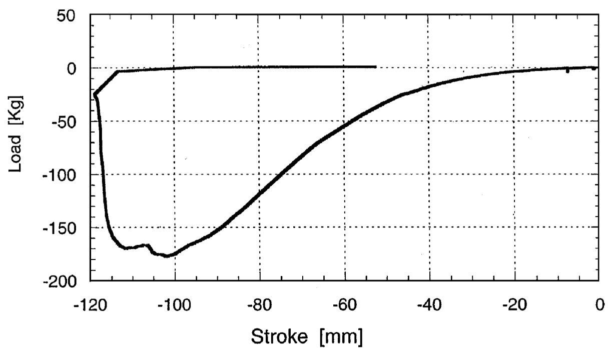

Fig. 9. — Graphic results of first test

aspect of the patella, the uniplanar cut patellae fractured at an average force of 350 kg (340 and 360 kg respectively) and the dome-shaped patellae fractured at an average force of 500 kg (480 kg and 520 kg respectively) (fig. 11a, 11b).

DISCUSSION

The purpose of this study was to evaluate the strength of the bony patella following a new method of preparation of the patella during total knee arthroplasty, by having it reamed into a dome shape with a dense circumferential wall and to compare its strength to the regular uniplanar cut.

Three combinations of tensile and compressive tests were done with the IDWA apparatus that used a femoral component opposing the patella to replicate the structure of the prosthetic knee.

The biomechanical tests imitated three possible patterns of fracture experienced clinically with the natural patella.

In the first test, the resistance of the patella to tensile forces applied to the soft tissue was evaluated. We observed that the soft tissues were torn at a force of 174 kg with no damage to the patella. These results indicated that following both types of preparation the patella was more resistant to tensile stress than its own ligament.

A similar result – torn soft tissue with no harm to the bony structures – was observed in the second test, which evaluated the strength of the patella under tension against internal impact load.

In the third test, in which the resistance of both types of patellae was evaluated against external impact, we observed that the force necessary to fracture the dome-shaped patella was greater than for the traditional uniplanar cut patella (500 kg vs. 350 kg).

We concluded that upon preparation of the bony patella for total knee arthroplasty, the dome-shaped patella with a dense circumferential wall, is at least as strong, if not stronger, in resisting external impact than the patella with the conventional uniplanar cut.

The bony patella with either shape remains stronger in resisting tensile forces than the quadriceps and patella ligaments.

These results encourage our use of our novel patellar implant with a concave undersurface.

The inset position of the concave implant within the borders of the circumferential wall appropriately fits the dome shape of the bony patella.

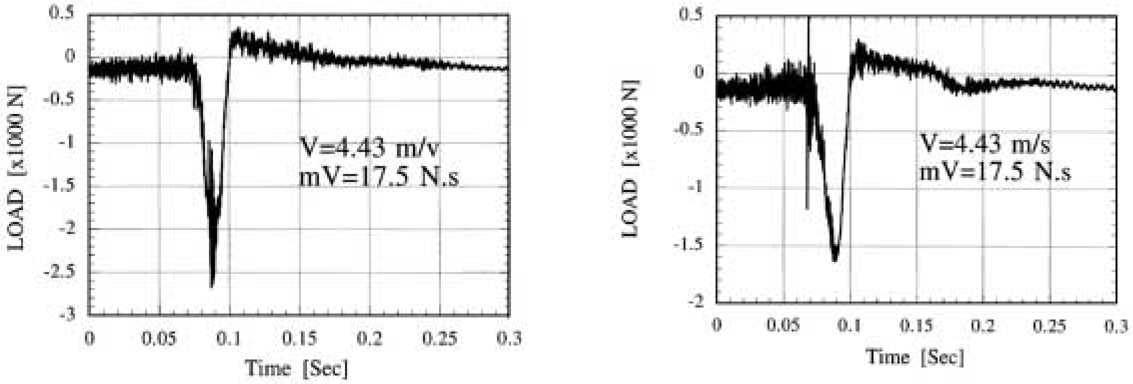

Fig. 10. — Graphic results of second test

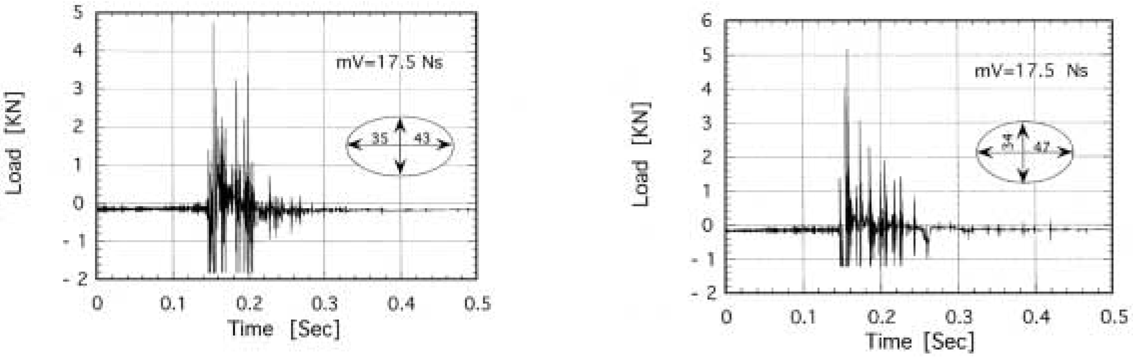

Fig. 11a. — Graphic results of the third test with uniplanar cut patellae

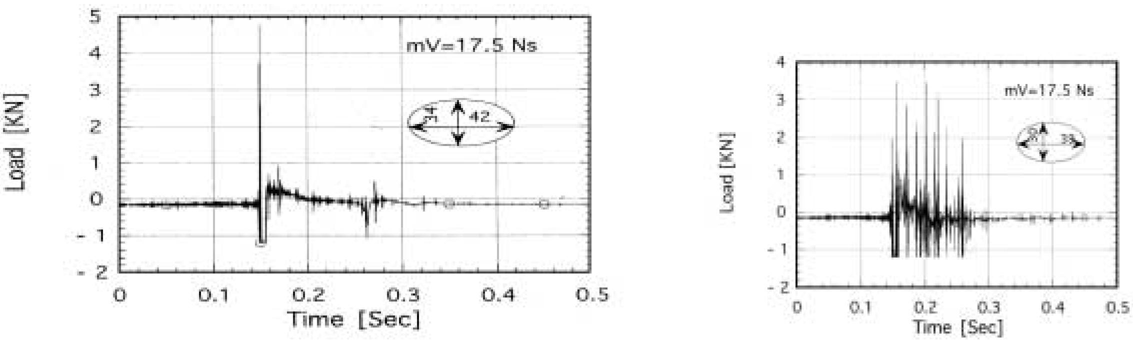

Fig. 11b. — Graphic results of the third test with dome-shaped patellae

REFERENCES

1. Dennis D. A. Patellofemoral complications in total knee arthroplasty : a literature review. Am. J. Knee Surg., 1992, 5, 156-166.
2. Hsu H. P., Walker P. S. Wear and deformation of patellar components in total knee arthroplasty. Clin. Orthop., 1989, 246, 260-265.
3. Mendes D. G., Said M., Head S., Sabo E., Nachman R., Boss J. H. Biomechanical and surgical solutions for patellar implant in total knee arthroplasty. Orthopedics, 1999, 22, 949-951.
4. Tria A. J., Harwood D. A., Alicea J. A., Cody R. P. Patellar fracture in posterior stabilized knee arthroplasties. Clin. Orthop., 1994, 299, 131-138.

SAMENVATTING

O. SCHWARTZ, M. LEVIN, A. ROTEM, D. G. MENDES. Vergelijkende biomechanische studie bij totale knie prothesis van de breekweerstand van de beenderige patelia voorbereidt met ofwel een koepelvormige of een vlakke zaagsnede.

Drie tests werden uitgevoerd op telkens 4 kadaver patellae. Twee hiervan werden voorbereidt met een vlakke snede, de twee andere in koepel vorm met een bewaarde botwal. De rest dikte van de patella bedroeg telkens 15 mm. Een apparaat mat de impact van een vallend gewicht. Een eerste test mat de weerstand van de patella aan trekkracht, een tweede mat de weerstand van de patella onder spanning, tegen belasting : telkens begaven de weke delen zonder beschadiging van de patella. In een derde test werd de patelia weerstand onder directe belasting zonder spanning gemeten : de kracht nodig om de patella te breken bedroeg 500 kg bij de koepelvorm en 350 kg bij de vlak geprepareerde patella. De koepelvorm is dus duidelijk beter tegen uitwendige druk bestand. Voor de auteurs is dit de rationale voor het gebruik van een patella prothesis met een ondervlak in concave koepelvorm.

RÉSUMÉ

O. SCHWARTZ, M. LEVIN, A. ROTEM, D. G. MENDES. Étude biomécanique comparative de la résistance mécanique de la rotule après une coupe plane ou en dôme dans l'arthroplastie par prothèse du genou.

Les auteurs ont réalisé une étude de la résistance mécanique de la rotule après préparation par une coupe classique ou par une coupe en dôme, dans l'arthroplastie prothétique du genou. Ils ont utilisé 4 rotules de cadavre pour réaliser plusieurs tests. Deux des quatre rotules ont été préparées avec une coupe classique, deux avec une coupe en dôme conservant un mur périphérique, au moyen d'une fraise concave. L'épaisseur des rotules après préparation était de 15 mm. Les tests ont été réalisés au moyen d'un appareil qui produisait des impacts par la chute de poids. Les deux premiers tests portaient sur la résistance de la rotule à des forces de tension et à l'impact d'une charge sous tension : dans ces deux tests, les tissu mous ont été rompus sans dégâts osseux à la rotule. Le troisième test évaluait la résistance de la rotule à un impact sans mise en tension : il fallait pour fracturer la rotule une force plus importante après préparation en dôme qu'après préparation classique (500 kg contre 350 kg). Dans l'arthroplastie par prothèse totale du genou, la préparation de la rotule osseuse en forme de dôme avec conservation d'un mur périphérique a donné une meilleure résistance à un impact externe que la préparation par une coupe classique plane. Cette constatation a été à la base de l'utilisation par les auteurs d'un implant patellaire en forme de dôme, à surface inférieure concave.