Strength and Voluntary Activation of Quadriceps Femoris Muscle in Total Knee Arthroplasty with Midvastus and Subvastus Approaches

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Abstract: To determine and compare the influence of 2 different approaches on quadriceps femoris muscle function in total knee arthroplasty (TKA), 20 patients (14 women, 6 men) with bilateral knee osteoarthritis underwent a 1-stage bilateral TKA. Surgical approaches (subvastus, midvastus) were performed by a random selection. Measurements of quadriceps voluntary activation and maximal voluntary contraction were estimated by a twitch interpolation technique before, 3 and 6 months after TKA. Knee pain was quantified by the Lewis Score. There was no difference between the 2 approaches at 3 and 6 months after TKA with regard to maximal voluntary contraction ($P = 0.84$, F = 0.041) and voluntary activation ($P = .863$, F = 0.031). In the subvastus group was a significantly higher knee pain until 6 months after surgery ($P = .02$). The subvastus approach for TKA does not provide any advantages compared with the midvastus approach with respect to the quadriceps femoris muscle strength in the early postoperative period. Furthermore, the subvastus approach caused significantly more pain postoperatively. **Key words:** osteoarthritis, knee, arthroplasty, approach, muscle strength, arthrogenous muscle inhibition, twitch interpolation.

Total knee arthroplasty (TKA) is widely used in the treatment of severe knee osteoarthritis (OA) to relieve pain and to restore knee function. Despite the current success of TKA, quadriceps weakness persists even years after surgery [1]. The loss of muscle strength is an important determinant of disability in patients with OA before and after TKA [2,3]. The reduction in voluntary activation (VA) of the muscle is considered to be among the mechanisms involved in the decline in muscle strength [4]. These VA deficits are at least in part reversible after TKA when compared with control subjects and may result in decreased effectiveness of physical therapy and rehabilitation that is focused on increasing muscle strength after surgery. Therefore, the improvement of exercise therapy and muscle strength within the first month after surgery is an important outcome measure in investigations in the effectiveness of TKA. Several studies have investigated the changes in muscle strength and pain after TKA [1,5,6], but few studies reported the effects of different surgical procedures on the quadriceps femoris muscle, especially the influence of surgical approaches on strength and VA of knee extensor mechanism [6-8].

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Currently, the medial parapatellar and the midvastus approaches have been the most popular arthrotomy for exposure in TKA. These approaches violate the quadriceps tendon or the vastus medialis muscle proximal to its insertion into the proximal pole of the patella. An alternative approach in TKA is the subvastus approach, which may preserve the extensor mechanism from surgical trauma.

We hypothesized that VA and quadriceps strength recovery are faster using the subvastus approach because of the theoretical advantage of this arthrotomy, which may preserve an intact extensor mechanism. The purpose of this study is to investigate the short-term effects of the subvastus and midvastus approaches on quadriceps femoris muscle torques, VA, and pain behavior after bilateral simultaneous TKA to provide a better understanding on the extent different approaches in TKA can influence VA and muscle strength of the quadriceps femoris muscle.

Material and Methods

Patients

Twenty patients (14 woman, 6 men) with bilateral degenerative OA of the knee were selected for this study and underwent a 1-stage bilateral TKA. All patients had knee pain and stiffness and fulfilled the American College of Rheumatology criteria for knee OA [9]. Anteroposterior and lateral radiographs confirmed the presence of bony changes in each patient, revealing grade III or IV OA, as assessed by the Kellgren-Lawrence Scale [10]. No other significant neuromuscular or skeletal pathologies were present. At the time of surgery, age of subjects ranged from 56 to 81 years (mean, 71.2 years; SD ±5.7), and body mass index ranged from 22.7 to 40.7 kg/m^2 (mean, 30.4 kg/m^2; SD ±5.6). All patients received an unconstrained, bicondylar implant without patella resurfacing (Natural-Knee prosthesis Natural-Knee prosthesis, Sulzer Orthopaedics Ltd., Baar, Switzerland) with either a bilateral cementless (n = 5) or cemented (n = 15) fixation. After a midline skin incision identical for all patients, 1 knee was exposed by the midvastus approach according to the technique of Engh et al [11], and the other using the subvastus approach as described by Hoffman et al [12]. The decision as to which approach each knee would receive was made in such a way that the approach as well as the operated side was randomized regardless of the severity of joint damage. We prepared 20 cards in closed envelopes, 10 cards with the instruction to perform the subvastus approach on the left side and the midvastus approach on the right side and 10 cards conversely (midvastus—left, subvastus—right). At the time of operation, the surgeon received one of the closed envelopes by a random selection. All patients underwent the department's standard inpatient rehabilitation program for 10 days, and an additional outpatient rehabilitation program continued for 4 weeks after discharge.

Evaluation

The experimental procedure consisted of the evaluation of the maximal voluntary contraction (MVC) force, VA of the quadriceps femoris muscle, and the knee pain quantified by the Lewis score [13]. Patients were examined 1 day before and at 3 and 6 months after TKA. The local ethics committee approved all experimental procedures.

Twitch-Interpolation Technique

If voluntary muscle fibers are completely activated, superimposed external muscle stimulation (twitch) will not produce any additional muscle force. Conversely, if voluntary muscle contraction is incomplete, additional force is generated by superimposed muscle stimulation. This principle allows quantification of the maximal voluntary muscle activation.

Provided that the subjects' generated force is greater than or equal to 25% of the MVC, additional forces produced by the superimposed electrical stimulation are assumed to have a linear relationship to the voluntarily elicited initial force [14,15]. We performed linear extrapolation at 5 twitch torque levels (25%, 50%, 75%, 90%, and 100% of MVC force) to the twitch torque intercept at theoretical muscle relaxation. The VA was defined as [16-18]

$$\mathrm{VA}(\%) = 1 - \frac{\text{twitch torque at MVC[Nm]}}{\text{twitch torque at resting muscle[Nm]}} \times 100\%.$$

We used a Dantec Counterpoint MK II (Dantec Dynamics A/S, Skovlunde, Denmark) constant current stimulator to apply single, square-wave stimuli with 100-mA amplitude and 500-μs duration. Dedicated software developed at our institution was used for data acquisition and for highly sensitive, automated twitch detection as described by Hales and Gandevia [19]. The sensitivity and reliability of this method have been investigated earlier [15,16,19].

Experimental Procedure

Isometric force was measured with a specially designed dynamometer. Patients were seated up-