Proprioception after total knee arthroplasty

A comparison with clinical outcome

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ABSTRACT – We determined proprioception in replaced and unreplaced arthrotic knees by measuring threshold levels for the perception of passive knee motion. In addition, results of these proprioception measurements were compared with the clinical outcomes in patients with a total knee arthroplasty.

Threshold detection levels were significantly higher in the replaced than in the unreplaced knees. Moreover, detection-failure rates were significantly higher in the replaced knees as well. In contrast to this diminished movement sense in the replaced knees, clinical examination of these knees showed good or excellent outcome in all cases. A correlation between the clinical outcome and the ability to perceive passive motion in either patient group could not be found.

We hypothesize that our findings may be due to the operative removal of intraarticular receptor-rich tissue that is affected by arthrosis. This would not only contribute to marked clinical improvements but also to a significant decrease in proprioception.

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In recent years, proprioception has been used to describe functional deficits in arthrotic knees both by joint-position sense measurements (Marks 1996, Sharma and Pai 1997) and threshold detection measurements of passive knee motion (Pap et al. 1998a, 1998b). Several attempts have been made to use proprioception measurements to evaluate therapeutic approaches in arthrosis, both nonoperative (Jerosch et al. 1997, Hurley and Scott 1998) and operative (Attfield et al. 1996), as regards the results of knee replacement and especially the importance of the posterior cruciate ligament (PCL) (Cash et al. 1996, Simmons et al. 1996a, Lattanzio et al. 1998).

Studies of proprioception in knees with PCL retaining and PCL-substituting prostheses, however, have given contradictory results (Warren et al. 1993). Even the effect of knee replacement on proprioception in general remains elusive. Some authors report significant improvement in proprioception after knee replacements (Barrett et al. 1991, Warren et al. 1993), while others have found no differences between replaced and unreplaced knees (Barrack et al. 1983, Ishii et al. 1997); even a reduction in proprioception after knee replacements has been reported (Fuchs et al. 1998).

These observations are confusing, since many of the intraarticular structures, altered or removed during total knee replacements, have been reported to be of importance for knee proprioception (Johansson et al. 1991, Corrigan et al. 1992, Haus et al. 1992, Clark et al. 1996, Jerosch et al. 1996, Del Valle et al. 1998).

The relationship between proprioception and clinical outcome in patients with a knee arthroplasty has rarely been investigated. However, such comparison of proprioceptive data, with clinical results, is important for the evaluation of these measurements of proprioception.

We investigated proprioception in replaced and unreplaced arthrotic knees, using an established method of measuring threshold levels for perception of passive motion. These measurements were compared to the clinical outcomes in patients with total knee arthroplasties to determine whether measurements of proprioception area of value in assessing of results of total knee arthroplasties.

Methods and patients

Measurements of the detection of passive knee joint motion were done, as described previously (Pap et al. 1997, 1999). Subjects were seated on a custom made test chair with the foot and ankle of the test limb immobilized by a rigid inflated air-splint to minimize cutaneous sensations. An internal pressure of 4kPa (30 mm Hg) ensured that the ankle remained fixed, without occluding the circulation. A similar air-splint was put under the thigh 100–150 mm proximal to the knee joint. The tests were performed with the patient wearing dark glasses and listening to white noise through headphones. The air-splint around the leg was fixed to a shaft-joint system in such a way that movement occurred in the knee only. The system was directly connected by a wire to a winding drum moved by a stepper motor. This commercially-available motor operating in microstepping mode is used as a standard device for proprioceptive control (Proudlock and Scott 1998). Speed and direction of the stepper motor were PC-controlled. With this device we performed passive extension or flexion movements around the subject's knee fixed in space. Each trial started from a knee-flexion angle of 45°, and consisted of a passive ramp-and-hold movement (i.e., movement with an 'instant' onset, constant velocity movement and an 'instant' stop) having an amplitude of 10° and an angular velocity of 0.6°/s. By pressing a button, subjects signaled when they felt the beginning and the end of the movement.

The threshold for perception of the start of motion (TPSM [°]) was determined by multiplying the time from the start of the movement to the subject's first "button-press" (t_m [s]) by the angular velocity (v_a = 0.6°/s):

$$\text{TPSM } [°] = t_m \text{ [s]} \times 0.6 \text{ °/s}$$

The time from the end of the movement to the subject's final "button-press" (t_s [s]) was also measured. To compare this data at different angular velocities, the time from the end of the movement to the subject's final "button-press" (t_s [s]) was multiplied by the angular velocity of 0.6 °/s to determine the threshold for perception of the end of motion (TPEM) in degrees:

$$\text{TPEM } [°] = t_s \text{ [s]} \times 0.6°/\text{s}$$

This was used as a measure for the "stop-sense". If the subjects did not press the button after the passive knee movement began until its end, this part of the test was classified as a movement-detection failure. Likewise, if no "button-press" occurred after the end of the movement, a stop-detection failure was assumed.

The test protocol included 6 trials per knee at an angular velocity of 0.6°/s, mixed wih passive flexion and extension movements, as in previous studies by our group (Pap et al. 1997, 1998a, b, 1999) and others (Hall et al. 1995, Simmons et al. 1996b).

Measurements were made in 15 patients who underwent unilateral TKA for primary arthrosis in our department. Radiographic assessment before the implantation showed stage IV arthrosis, according to Kellgren and Lawrence (Kellgren and Lawrence 1957) in all knees that had been operated on. We used the Natural-Knee prosthesis (Sulzer) without patella resurfacing. Measurements of proprioception were done during a series of follow-up investigations in our department. The average age of the patients was 60 (56–73) years, and 6 were men. Both knees were tested at an average of 4.6 (4–6) years after surgery. In unoperated knees, all 15 patients had clinical and radiographic signs of early arthrosis with at least three of the following criteria (Altman et al. 1987): 1. Age > 50 years, 2. Morning stiffness < 30 minutes, 3. Crepitus on movement of the knee joint, 4. Bony tenderness at the knee joint margins, 5. Bony enlargement palpable or visible, 6. No palpable warmth. Radiographic assessment showed arthrosis stage II, according to Kellgren and Lawrence (1957), in all of these knees.

As controls, we used an age- and sex-matched group of 15 healthy subjects (mean age 60 (56–73) years; 6 men) who were staff members in our department or their relatives. None of them had any clinical evidence of knee arthrosis or a history of serious damage to either knee.

Subjects with neurological conditions, musculoskeletal disease other than arthrosis, previous

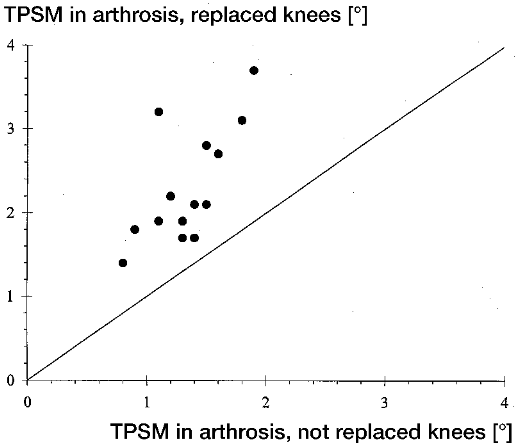

Figure 1. Comparison of the thresholds for perception of the start of passive motion (TPSM) between the replaced and the contralateral, unreplaced knees.

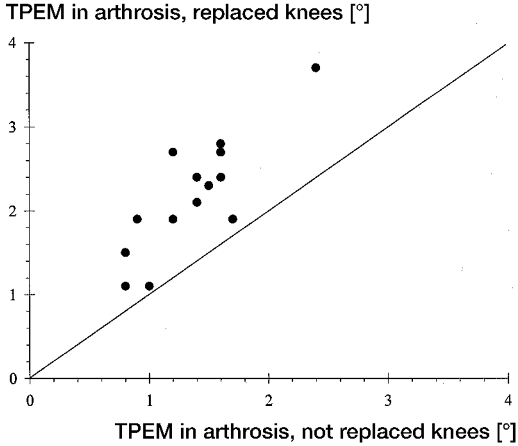

Figure 2. Comparison of the thresholds for the perception of the end of passive motion (TPEM) between the replaced and the contralateral, unreplaced knees.

knee operations other than unilateral knee joint replacement or recent injury to the lower extremity, were not included in this study.

In addition to measurements of movement sense, the patients were assessed using the American Knee Society score (Insall et al. 1989).

These studies were approved by the local ethics committee. Comparison between groups was performed using the paired t-test. P-values of < 0.05 were considered significant. Correlation between clinical results and measurements of the detection of passive knee joint motion was evaluated with the Spearman rank order correlation.

Results

In the unoperated knees of the arthrosis patients, individual detection thresholds for perception of the start of passive motion (TPSM) ranged between 0.9° and 1.9° with an overall mean TPSM of 1.4° (SD 0.4°). In contrast, in the replaced knees, individual threshold levels ranged between 1.4° and 3.9° with an overall mean TPSM of 2.2° (SD 0.9°). Thus, thresholds for perception of the start of passive motion (TPSM) were significantly higher in the replaced than in the unoperated knees (Figure 1). In the controls, individual TPSM values ranged from 0.5° to 2.1° with an overall mean TPSM of 1.1° (SD 0.5°) and were thus significantly lower than in the replaced knees but not different from the unoperated knees.

Measurements of the thresholds for perception of the end of motion (TPEM) revealed similar results. In the unoperated knees, individual threshold values for perception of the end of motion ranged from 0.8° to 2.5°, with an overall mean TPEM of 1.3° (SD 0.5°). In contrast, in the replaced knees, threshold values for perception of the end of motion ranged from 1.1° to 3.7° with an overall mean TPEM of 2.1° (SD 0.8°). Again, thresholds for perception of the end of motion (TPEM) were significantly higher in the replaced than in the unoperated knees (Figure 2). In the controls, individual TPEM values ranged from 0.6° to 2.2°, with an overall mean TPEM of 1.2° (SD 0.5°) and were again significantly below the values in the replaced knees but not different from those in the unoperated ones.

Analysis of the movement-detection failures showed significantly higher failure rates in the replaced knees than in the unreplaced and control knees. In addition, analysis of the stop-detection failures showed increased failure rates in the replaced knees as well (Table).

Unlike this diminished perception of passive motion in the replaced, compared to the unreplaced knees, clinical examinations of the replaced knees yielded good or excellent results in all cases, with a mean Knee Society score of 89 (SD 8.9, range 71–99) and a mean Functional score of 82 (SD 9.4, range 65–100). None of the

Failure rates of movement and stop-detection measurements in replaced, unreplaced and control knees (mean and range)

	Replaced knees n 15	Unreplaced knees n 15	Control knees n 15
Movement-detection failures	1.3 [a] (0–3)	0.13 (0–1)	0.17 (0–1)
Stop-detection failures	1.4 [a] (0–3)	0.23 (0–1)	0.10 (0–1)

[a] $p < 0.05$ vs. unreplaced and vs. control knees

replaced knees showed signs of instability, and the patients felt no pain.

There was no correlation between the clinical outcome and the ability to perceive passive motion (Figure 3).

Discussion

Detection thresholds of passive knee motion are used to evaluate proprioception in ACL deficiency and arthrosis of the knee (Barrack et al. 1983, Corrigan et al. 1992, Wright et al. 1995) and to assess postoperative results (Lephart et al. 1992, Cash et al. 1996, Simmons et al. 1996b). Slow angular velocities of passive knee motion (0.1°/s–5°/s) are are mainly used to measure thresholds for perception of the beginning of passive motion (Corrigan et al. 1992, Lephart et al. 1992, Hall et al. 1994, Refshauge et al. 1995, MacDonald et al. 1996). In recent studies, however, we have shown that measurements of threshold detection levels of passive motion alone are not sufficient to evaluate proprioceptive deficits, but analysis of failure should also be included in the evaluation of movement-sense measurements (Pap et al. 1997, 1998a, 1999). At angular velocities of about 0.6°/s, detection-failure rates in arthrotic knees are below 25% (Pap et al. 1998b), so at this angular velocity the individual threshold detection level can be determined for each patient. Therefore, in the present study, we used an angular velocity of 0.6°/s, which, in addition, compares well with recent studies on proprioceptive changes after knee arthroplasties using similar angular velocities of 0.5°/s (Cash et al. 1996, Simmons et al. 1996a, b). As a starting position for our measurements, we chose 45° of knee flexion because mid-range flexion angles of 30°–60° had been used frequently in similar measurements (Barrack et al. 1989, Corrigan et al. 1992, Wright et al. 1995, Simmons et al. 1996b, Borsa et al. 1997). Moreover, previous studies performed by our group (Pap et al. 1997, 1998a, b, 1999) and others (Hall et al. 1994, 1995, Simmons et al. 1996b) have shown that, starting from mid-range knee flexion, there are no differ-

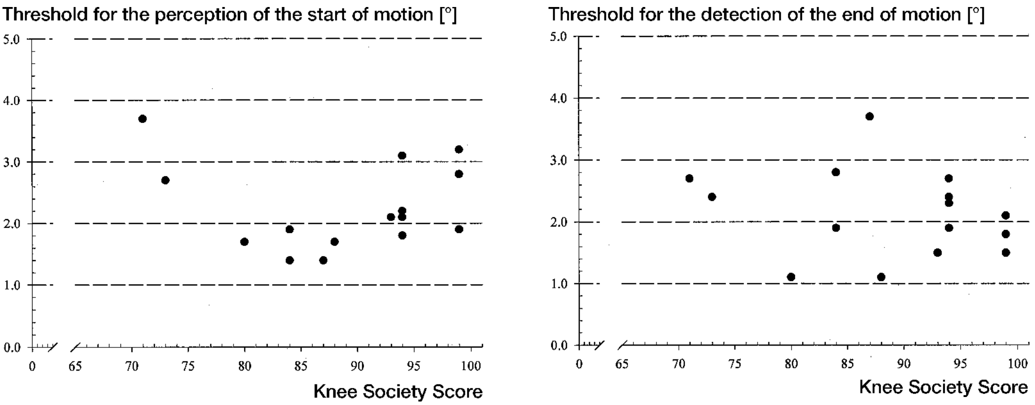

Figure 3. Relationship between the Knee Society scores and the thresholds for perception of the start (TPSM) and end of motion (TPEM) in knees with TKA.

ences in the threshold detection levels between extension and flexion movements. This makes it possible to use results consisting of recordings towards extension and flexion in a similar way, although some information might thereby be lost. Since several reports indicate that knee proprioception is more sensitive at the two extremes of extension (Hall et al. 1994, Fridén et al. 1996), studies should also include starting knee flexion angles between 0° and 20°, with a separate evaluation of flexion and extension movements.

Our findings show a marked loss of the perception of passive motion after a TKA, compared to the contralateral knees with early arthrosis and to healthy controls without knee damage. These finding seem to refute previous studies, in which proprioception improved after TKA (Barrett et al. 1991, Warren et al. 1993). However, in these studies, assessment of joint-position sense was performed for proprioception measurements and the method differed from that for movement-sense measurements. Moreover, since other studies on joint-position sense after TKA revealed either no improvement in proprioception (Ishii et al. 1997) or even a worsening of it (Fuchs et al. 1998), differences in testing methods may be a cause of this controversy. In addition, neither the present study nor those referred to above compare proprioception before and after TKA in the same knees but between replaced, unreplaced and normal knees. Such comparisons, however, are biased by interindividual differences in proprioception (Pap et al. 1998a), age-related decline in proprioception (Skinner et al. 1984), early arthrosis in the contralateral or the control knees (Sharma 1999), type of implant (Warren et al. 1993), etc., which might also lead to contradictory results. Therefore, further studies comparing proprioception before and after TKA in the same patients are needed.

There is general agreement that intraarticular receptors in the anterior cruciate ligament and the joint capsule contribute substantially to joint proprioception (Cash et al. 1996). Therefore, removal of these structures could affect proprioceptive parameters, such as the perception of passive motion.

On the basis of our findings, we hypothesize that the loss of the perception of passive motion in the replaced knees is probably due to the implantation of a TKA and, although speculative, that the removal of intraarticular structures at TKA implantation might contribute to loss of the sense of movement.

Changes in proprioception after TKA, however, do not necessarily mean an unsatisfactory clinical outcome. Despite an obvious worsening of the perception of passive motion after TKA, good or even excellent clinical outcome could be achieved. It is important to stress that none of the replaced knees was unstable. Therefore, instability that has been shown to reduce proprioception in replaced knees (Attfield et al. 1996) cannot explain the differences between the replaced and unreplaced knees in our study. It is very possible, however, that the impaired proprioception in TKA knees is masked by more obvious changes (pain relief, improved walking ability, etc.), which primarily affect a traditional knee score as a measure of success after TKA.

We hypothesize that the good clinical outcome in TKA in this and other studies (Cameron and Jung 1993, Knight et al. 1997, Bassett 1998, Duffy et al. 1998) may be, at least in part, due to the removal of intraarticular receptors affected by arthrosis (Franchi et al. 1995). In consequence, this leads not only to a reduction in pain (Whiteside 1994), but also in afferent signals from the joint receptors which cause arthrogenous muscle inhibition (Hurley et al. 1997) and loss of function in patients with arthrosis of the knee.

Thus, measurements of thresholds for the perception of passive motion seem to have limitations in evaluating of the results after a TKA. Further studies are needed to show whether other methods for measuring proprioceptive parameters—e.g., threshold hunting paradigm (Weiler and Awiszus 1998)—can be used in the neurophysiological assessment of replaced knees.

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