Quantitative evaluation of gait pattern in patients with osteoarthrosis of the knee before and after total knee arthroplasty. Gait analysis using a pressure measuring system

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Abstract: Using a pressure measuring system, we quantitatively evaluated gait pattern in patients with osteoarthrosis (OA) of the knee before and after total knee arthroplasty (TKA). In the OA group, the stance time was longer, and the average vertical component of the floor reaction force (AVF) was lower than the values in normal age-matched subjects. These gait parameters correlated with the clinical score. These results suggest that changes in the gait parameters reflect gait patterns that reduce load on the knee. The center of pressure (COP) under the foot was correlated with the axial alignment of the lower limb in the mid-stance phase. In the TKA group, the clinical scores and gait parameters were improved 12 months after surgery compared with the preoperative values. The COP in the mid-stance phase moved inward after the TKA. However, in patients examined more than 2 years after a TKA, stance time and AVF did not reach normal levels, despite the patients' good clinical scores. These findings indicate that the gait pattern before surgery continues although pain on walking is reduced early after a TKA. Gait evaluation with a simple pressure measuring system revealed the changes in gait that are difficult to define by subjective clinical assessment.

Key words: gait analysis, osteoarthrosis of the knee, total knee arthroplasty, pressure measuring system

Evaluation of the functional capacity of knee joints has been performed by static radiographic examination and by clinical scoring systems. However, these methods are not suitable for preoperative evaluation and postoperative observation, as OA manifests its symptoms in dynamic situations. Chao and Stauffer and Stauffer et al. first reported quantitative gait analysis for patients with prosthetic knee replacements. Since those studies, there have been a number of studies of the relationship between changes in gait parameters and clinical symptoms or the axial alignment of the lower extremities.

However, since a large measurement apparatus is required for gait analysis, it has not been widely used for pre- and postoperative evaluations. In the present study, we performed gait analysis of patients with OA of the knee, using a simple pressure measuring system, and we quantitatively evaluated changes in gait pattern in these OA patients after TKA.

Subjects and methods

Study design

Study I: Gait analysis in patients with OA of the knee

The subjects were 53 women with OA of the knee who were examined at Tottori University Hospital in the period November 1995 to October 1997 (OA group; mean age, 68.2 years; range, 50–85 years). Of these 53 patients, 38 showed bilateral involvement, and in these patients the more severely affected knee (as shown by radiography) was evaluated.

Fourteen age-matched healthy women without physical or radiographically shown disorders in the bilateral lower extremities were tested as controls (control group; mean age, 68.0 years; range, 61–78 years), and the left lower extremity of each subject was evaluated.
After radiographic and clinical evaluations, gait analysis of each subject was performed with a pressure measuring system. Gait parameters in the OA and control groups were compared, and the relationships between the gait parameters and the clinical scores or the axial alignment of the lower extremity, measured by radiography, were analyzed.

**Study 2: Gait analysis in TKA patients**

TKA patients were divided into TKA groups A and B according to whether the first gait analysis had been performed before TKA.

**TKA group A**
The subjects were 16 women who had undergone TKA for OA at our hospital in the period December 1995 to September 1997. They were aged 64–84 years (mean, 73.0 years) at surgery. Four patients underwent TKA in the contralateral knee within 6 months after the first surgery. Gait analysis and clinical evaluation of these patients were performed just before surgery and at one or more of the following times postoperatively: 3 months (12 patients), 6 months (15 patients), and 12 months (12 patients).

**TKA group B**
The subjects were 22 women who had undergone TKA for OA at our hospital in the period December 1985 to October 1995. Of the 22 patients, 11 had undergone bilateral TKA, and in these patients the lower extremity that was first operated on was evaluated. In 2 of the 22 patients, high tibial osteotomy had been performed in the contralateral knee. They were aged 60–82 years (mean, 72.2 years) at the time of first evaluation and gait analysis and clinical evaluation were performed at the time of follow-up observation (mean postoperative period, 4.8 years; range: 2.0–10.8 years).

TKA was performed by conventional techniques, and the patella was replaced in all patients. Full-weight walking started 2 or 3 weeks after the operation. A semiconstrained type of implant was placed in all knees for evaluation. An Osteonics (Allendale, NJ, USA) implant was used in all 16 knees in group A, and 10 PCA (Howmedica, Rutherford, NJ, USA) and 12 Osteonics implants were used in group B.

**Clinical evaluation**
The walking ability of the patients was evaluated clinically in terms of pain on walking (Table 1) according to the criteria for evaluating osteoarthritis of the knee proposed by the Japanese Orthopaedic Association, and passive range of motion of the knee was measured on physical examination. Clinical results are shown in Table 2. Single-stance anteroposterior radiographs of

<table>
<thead>
<tr>
<th>Table 1. Clinical evaluation of walking abilitya</th>
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<tbody>
<tr>
<td><strong>Pain on walking</strong></td>
</tr>
<tr>
<td>Walking 1 km or more usually with no pain, without regard to mild pain, rarely felt with certain activities</td>
</tr>
<tr>
<td>Walking 1 km or more regardless of pain</td>
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<tr>
<td>Walking 500 m or more, but less than 1 km without regard to pain</td>
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<tr>
<td>Walking 100 m or more, but less than 500 m without regard to pain</td>
</tr>
<tr>
<td>Walking indoors or nearby, but less than 100 m without regard to pain</td>
</tr>
<tr>
<td>Inability to walk</td>
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<tr>
<td>Inability to stand</td>
</tr>
</tbody>
</table>

a According to the criteria for evaluating osteoarthritis of the knee (1988: The Committee on Assessment Criteria for Knee Diseases and Treatments of the Japanese Orthopaedic Association). A normal subject’s score is 30 points

the lower extremities were used for evaluation. The severity of OA was evaluated according to Ahlbäck’s classification, and the anatomical femorotibial angle (FTA) was measured by the method of Bauer et al. Table 3 shows the radiographic results in all groups.

**Gait analysis**

**Apparatus**
The apparatus used was a pressure measuring system (MP-4800; Anima, Tokyo, Japan). The measurement plate (280 mm × 392 mm) had 2240 measuring sensors with a pressure sensitivity ranging from 0.1 to 4.0 kg/cm². The center of pressure (COP) was simultaneously determined by load-cells positioned at the four corners of the plate.

**Measurement methods**
In the center of the 6-m-long and 60-cm-wide walkway, two measurement plates were placed to be adjusted to the step length of each subject. Free walking with bare feet on the walkway was repeated several times, and the foot pressure distribution was sampled at 20 Hz. The data obtained at each sampling time were processed, and combined frames of the footprint and the path of the COP were determined (Fig. 1a). The following parameters were calculated from the pressure distribution data obtained while the subjects were walking with the least restriction:

(a) **Stance time**: Duration between heel strike and toe-off.

(b) **Percent pre-stance, percent mid-stance, and percent terminal stance phases**: The times of heel strike, foot flat (grounding of the fifth metatarsal head region), heel-off and toe-off, determined from the sequential instant foot print, and the durations