Comparison with other studies

The values for mortality for spine surgery (0.11%–0.20%) and primary TKA (0.066%) are similar to those reported in other large database studies [6-9,19-21]. In the present study, comorbidity burden (CCI ≥ 3) had the greatest impact both on in-hospital mortality and occurrence of major complications. In the National Surgical Quality Improvement Program, which examined outcomes for 3,475 patients undergoing spine surgery, identified age, and contaminated or infected wounds as independent predictors of mortality [10]. Pumberger et al. reported the highest odds for perioperative mortality for patients undergoing lumbar arthrodesis were among patients aged 75 years or older (OR, 4.35; reference: 45–46 years) and those with the comorbidities of congestive heart failure, coagulopathy, and liver disease [9]. Similarly, Memtsoudis et al. found that risk factors for mortality following TKA and THA included age (≥ 75 years; OR, 3.70), male gender, ethnicity, emergency admission, and comorbidity [8].

In these previous studies, each comorbid condition was analyzed separately. In the present study, we used the CCI because in elderly patients often present with multiple coexisting conditions. Our data demonstrate that presentation with coexisting conditions has a striking impact on postoperative adverse outcomes.

Risk profile also varies among surgical procedures. After adjusting for age, sex, and comorbidities, the risk for in-hospital death following lumbar arthrodesis or cervical laminoplasty was twice as high as the risk following TKA. There was no significant difference between lumbar decompression and TKA. Few previous studies have examined procedure-related risk differences among orthopaedic procedures. Memtsoudis et al. reported that TKA has a slightly lower risk of mortality than THA [8]. Deyo et al. demonstrated that lumbar arthrodesis, in particular complex fusion, compared with decompression alone, increased risk of 30-day mortality [5]. Although unadjusted factors may influence mortality rates, surgeons should be aware of the different risk profile among surgical procedures.

Conclusions

Our findings suggest that an assessment of perioperative risks in elderly patients undergoing orthopaedic surgery should be stratified according to comorbidity burden and type of procedures, as well as by patient's age. We believe that the findings of our study provide critical information for individual treatment recommendations for elderly patients.

Abbreviations

DPC: Diagnosis procedure combination; TKA: Total knee arthroplasty; THA: Total hip arthroplasty; CCI: Charlson comorbidity index; OR: Odds ratios.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

HC, HY, KT, and ST contributed to the conception and design of the study. HH, SS, ST, and KF contributed to the analysis, and all authors contributed to the interpretation. HC drafted the article; all authors revised it critically for important intellectual content and approved the final version submitted for publication. All authors read and approved the final manuscript.

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CASE REPORT

Cervical canal stenosis caused by progressive fusion and enlargement of cervical vertebrae with features of Proteus syndrome and Klippel–Feil syndrome

Shurei Sugita · Hirotaka Chikuda · Junichi Ohya · Yuki Taniguchi · Katsushi Takeshita · Nobuhiko Haga · Tetsuo Ushiku · Sakae Tanaka

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Abstract We report the case of a female who presented with progressive fusion and an enlargement of the cervical vertebrae. Her cervical deformity gradually progressed with age, and the abnormal bony protrusion into the spinal canal caused myelopathy. We resected the affected vertebrae to decompress the spinal cord and performed combined anterior-posterior spinal fusion. The progression of the spinal deformity and enlargement of vertebrae stopped after surgery. The enlargement of vertebrae in the present case resembled that observed in Proteus syndrome; however, autonomous vertebral fusion has not been reported previously in patients with this condition. Our report may help expand the knowledge on developmental spine disorders.

Keywords Proteus syndrome · Klippel–Feil syndrome · Enlargement of vertebral body · Cervical spine · Spinal deformity · Myelopathy

Introduction

Cervical spine deformity in childhood is a rare condition, and is known to be associated with several congenital diseases, including Klippel–Feil syndrome (KFS), Larsen syndrome, and Down syndrome [1]. Patients with cervical spine deformity may present without apparent symptoms in early childhood, but often develop various symptoms with age, such as neck pain, stiffness of the neck, and uncommonly, myelopathy [1, 2]. To our knowledge, spinal cord compression in a pediatric patient due to progressive enlargement of the cervical vertebrae has not been reported. We report the case of a 13-year-old female who presented with myelopathy due to progressive fusion and enlargement of the cervical vertebrae.

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Case report

A 9-year-old female presented with a neck deformity and imbalance of her shoulders, which had first been recognized by her parents when she was 5 years old. The patient was born without complications after a normal pregnancy. The patient's parents had both normal phenotypes. Her history of physical and mental development was normal. Except for her neck deformity, she was otherwise healthy, without abnormal joint laxity or any other skeletal deformity. There were no neurological symptoms at the time of presentation. Plain radiographs of the cervical spine showed scoliosis and vertebral fusion (Fig. 1a). Our presumed diagnosis was KFS, and we adopted a wait-and-see approach.

Three years after the initial visit, the patient presented to our clinic with slight gait disturbance, clumsy hands, and muscle weakness. A neurological examination revealed hyperreflexia and myelopathy. Plain radiographs demonstrated a marked progression of the cervical spine deformity and abnormal enlargement of the vertebrae and laminae (Fig. 1b). Computed tomography (CT) revealed fusion of multiple vertebrae and an abnormally bony protrusion into the canal (Fig. 2). Magnetic resonance imaging (MRI)

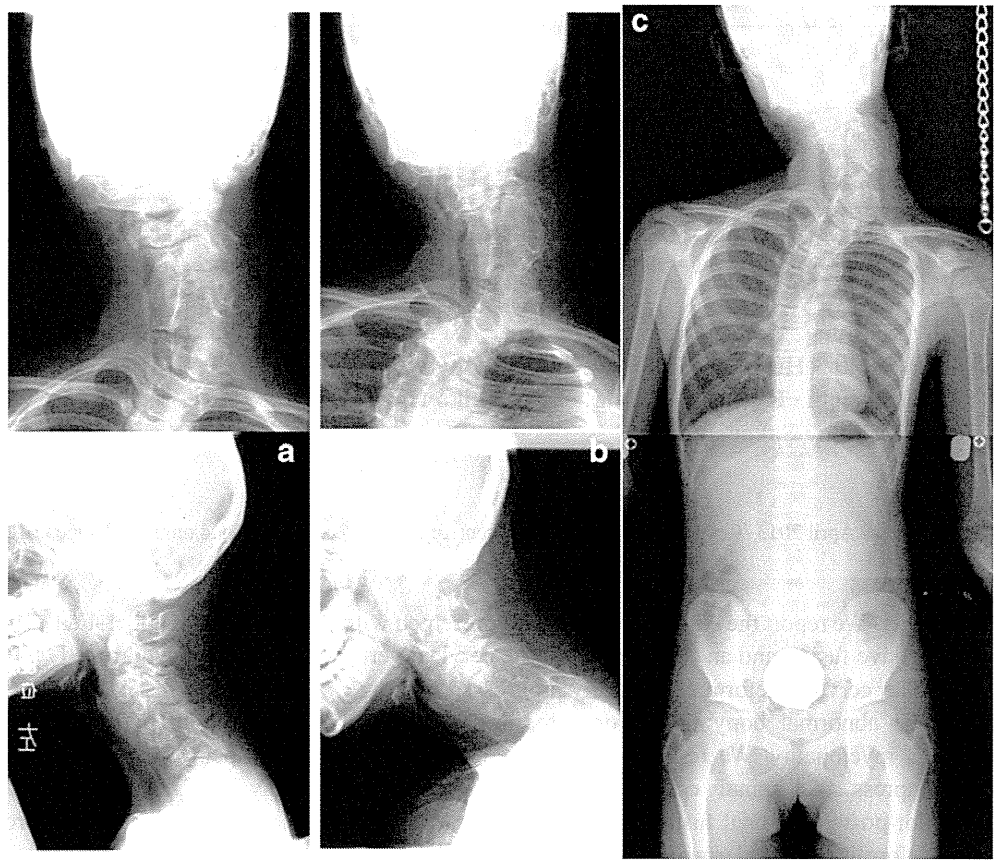

Fig. 1 Plain radiographs of the cervical spine taken at the ages of 9 (**a**) and 12 (**b**) years. The C1 vertebral body was enlarged and C3 and C4 body were fused, and cervical scoliosis was present (**a**). The fusion of the vertebrae and scoliosis progressed after 3 years (**b**). A radiograph of the whole spine showed shoulder balance impairment (**c**)

showed severe stenosis at the C2/3 and C3/4 level, with high intensity within the spinal cord on T2-weighted images (Fig. 3). To prevent further ingravescence of the myelopathy and cervical deformity, we performed surgery to decompress the spinal canal from the anterior and subsequently fused the spine (from occiput to T7) from posterior (Fig. 4a and b).

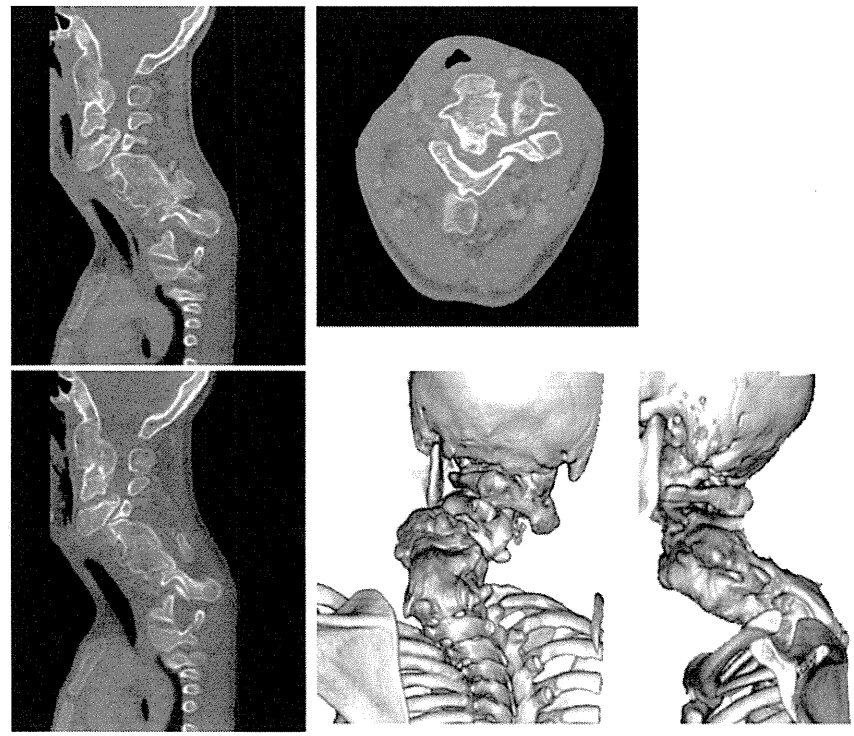

Fig. 2 Sagittal CT images showing protrusion of the abnormally enlarged bone into the spinal canal at the level of C2 and C3. All of the cervical vertebral bodies and lateral masses were almost fused except C2/3 and C3/4 level. The 3D reconstructed images showed the deformity of the cervical spine in detail

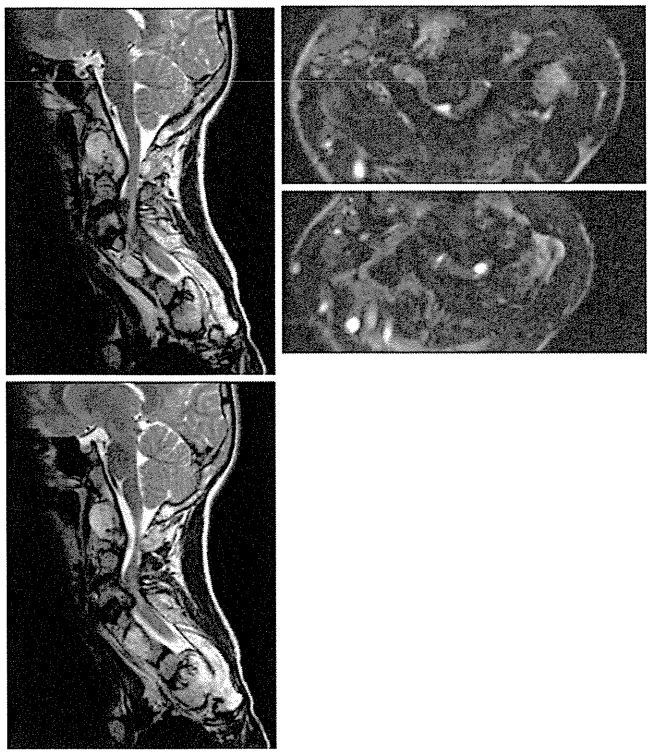

Fig. 3 Sagittal T2-weighed MR images showed spinal cord compression by the protruding bone at C2/3 and C3/4 level. High intensity of the spinal cord was observed in the axial view

Shortly after surgery, the patient's symptoms improved. The gait disturbance disappeared and muscle strength improved. A histological examination of the excised abnormally enlarged vertebrae showed a normal bone structure (Fig. 5). The progression of her spinal deformity has ceased during the subsequent 3 years of observation (Fig. 4c and d).

Discussion

Disproportional skeletal enlargement is known to be associated with several congenital diseases, including Proteus syndrome, Klippel–Weber–Trénaunay syndrome, Ollier's disease, Maffucci syndrome and Parkes Weber syndrome. [3–5]. The cervical lesion in the present case resembles a similar case that was previously reported as a radiological appearance of Proteus syndrome [6]. Proteus syndrome is a rare, sporadic, hamartomatous disorder [7] characterized by multifocal overgrowth of tissue derived from any of the three germinal layers. The disproportional overgrowth may be present at birth, but usually develops during childhood [8]. Despite the similarity in terms of the cervical lesion, our patient's course differed from that of Proteus syndrome in several points. First, she did not meet some of the criteria for a diagnosis of Proteus syndrome. She lacked signs of a nevus, specific tumors, vascular malformations, and the facial phenotype [9]. Additionally, progressive fusion of the vertebrae and laminae is not usually seen in Proteus syndrome.

KFS is a well-known syndrome showing congenitally fused vertebrae [10], which is characterized by congenital

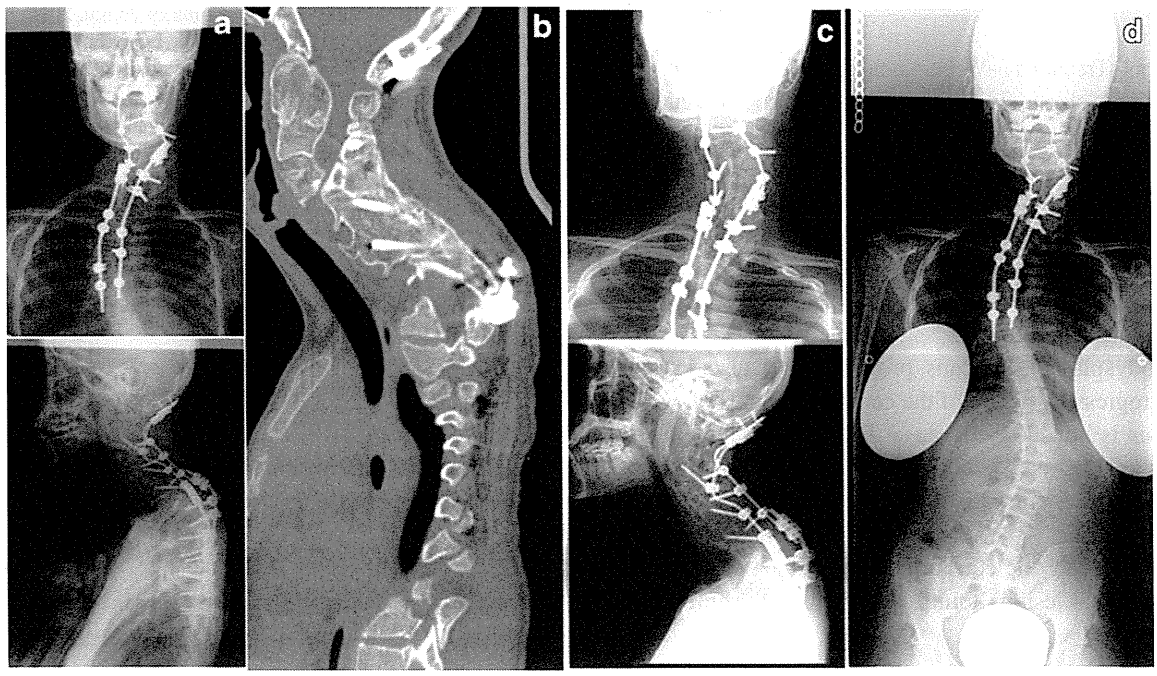

Fig. 4 Plain radiographs of the cervical spine taken at immediately after operation (**a**). Spine was fused from occiput to T7 level. An abnormally protruded bone was excised and iliac bone was grafted from C2/3 to C4/5 level (**b**). Three years after, progression of cervical deformity was ceased (**c**) but lumbar scoliosis appeared to compensate shoulder balance impairment (**d**)

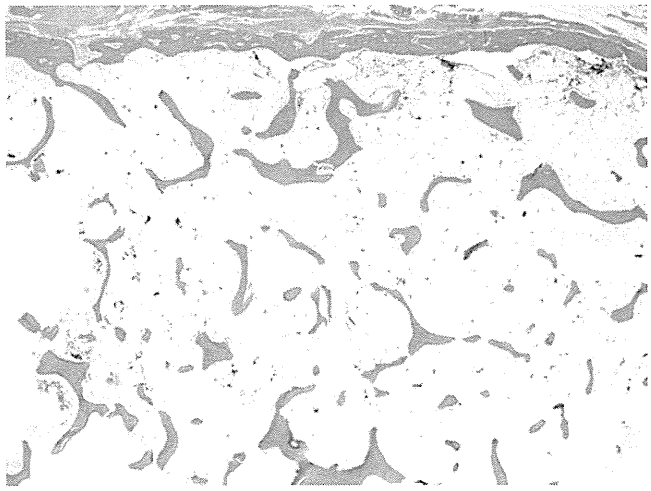

Fig. 5 Histological finding of excised abnormally enlarged bone. Structure was normal with slightly sclerosed trabecular bone. No neoplastic change was seen

fusion of at least two cervical vertebrae. Approximately half of the individuals with this syndrome exhibit the clinical triad of a short neck, a low posterior hairline and a limited cervical range of motion. Various skeletal and extraskeletal manifestations have been associated with KFS, but vary between individuals. The predominant associated manifestation in patients with KFS is scoliosis [11]. In adulthood, various degenerative manifestations may occur as a result of the congenital fusion process, which may contribute to the development of symptoms [2]. The present case shares several features with KFS, however, autonomous enlargement of the cervical vertebrae has not been reported in patients with KFS.

Klippel–Trénaunay–Weber syndrome is a rare phakomatosis with the classic findings of venous varicosities, cutaneous hemangiomata, and hypertrophy of the affected limbs. Involvement of the spinal cord has been reported in several cases [3]. However, we excluded this syndrome because our patient did not have any vascular abnormalities. Multiple enchondromatosis, such as Ollier's disease or Maffucci syndrome, were also excluded by meticulous observation of the patient's characteristics.

Fibrodysplasia ossificans progressiva is also known to cause progressive fusion of the cervical spine. However, this diagnosis is not likely because the fusion is limited to the posterior elements [1], and surgical treatment further accelerates the fusion in patients with fibrodysplasia ossificans progressiva.

In conclusion, the current patient shared several features of the cervical lesions found in Proteus syndrome or KFS, but did not entirely fulfill the criteria for either disease. The present case could be considered as an unclassified new type of mega-spondylodysplasia. However, to establish this case as a novel clinical entity, more reported similar cases are needed.

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Conflicts of interest No conflict of interest.

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The Knee 20 (2013) 291–294

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The Knee

Case report

Iliotibial band irritation caused by the EndoButton after anatomic double-bundle anterior cruciate ligament reconstruction: Report of two cases

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ABSTRACT

Two patients underwent arthroscopic anatomic double-bundle anterior cruciate ligament (ACL) reconstruction using the EndoButton for femoral fixation. The femoral tunnels were created by the inside-out technique through a far anteromedial portal. The patients postoperatively developed moderate lateral knee pain without instability. At the second-look arthroscopic evaluation, the two EndoButtons were removed. Both patients were completely asymptomatic several months after implant removal, implying that the EndoButtons caused the mechanical irritation in the iliotibial band. This is the first report describing removal of EndoButtons because of pain caused by friction with the iliotibial band. In anatomic ACL reconstruction, if the femoral tunnel exit is positioned near the lateral femoral epicondyle, care should be taken to prevent iliotibial band friction syndrome that could result because of the EndoButton.

1. Introduction

The EndoButton (Smith & Nephew Endoscopy, Andover, MA, USA) is a suspension device that has been widely used for femoral fixation in anterior cruciate ligament (ACL) reconstruction. It eliminates the need for an ancillary lateral incision in ACL reconstruction. Several authors have reported that femoral fixation with the EndoButton is a reliable and rigid technique [1,2]. Complications associated with EndoButton femoral fixation have been reported, including tunnel enlargement, EndoButton migration, symptomatic extensor mechanism irritation and intratunnel fixation [3–9]. However, there have been no reports of painful iliotibial band irritation caused by the EndoButton in ACL reconstruction. In this report, we describe two cases of painful iliotibial band irritation caused by the EndoButton in double-bundle ACL reconstruction.

2. Case presentation

Case 1. A 53-year-old woman twisted and injured her left knee in a landing during classical ballet. She underwent arthroscopic anatomic double-bundle ACL reconstruction using hamstring tendons. While creating the femoral tunnels during the ACL reconstruction, keeping the knee in deep flexion, two guidewires for the femoral tunnel were placed through a far anteromedial portal [10], while referencing the three-dimensional fluoroscopic navigation system [11,12]. The wires were then overdrilled for an adequate length using a cannulated drill, and the lateral femoral cortex was drilled through using an EndoButton drill (Smith & Nephew Endoscopy). After creating two femoral and two tibial tunnels, each graft for the anteromedial bundle or posterolateral bundle was passed through, and the EndoButton loop was flipped outside the femoral cortex (Fig. 1). Twelve months after the primary ACL reconstruction, the patient could perform classical ballet but felt moderate pain in the lateral left knee on motion. Examination using the Lachman test and N-test revealed negative results [13]. Postoperative side-to-side anterior stability measured with the KT-2000 arthrometer was 0.0 mm. The patient experienced tenderness on palpation of the iliotibial band above the EndoButtons. Plane radiographs and computed tomography of the left knee showed no migration of the EndoButtons. We proposed removing the EndoButtons at the time of planned removal of the tibial fixation material and second-look arthroscopic evaluation. The second-look arthroscopic evaluation was performed 24 months after the ACL surgery. These arthroscopic findings indicated that the reconstructed ACL showed excellent results with no meniscal and cartilaginous injury. During the second surgery, the iliotibial band was split and the two EndoButtons were removed (Fig. 2). There was no friction between the EndoButtons and lateral structures such as the popliteus tendon or lateral collateral ligament, which were covered with scar tissue beneath the thickened iliotibial

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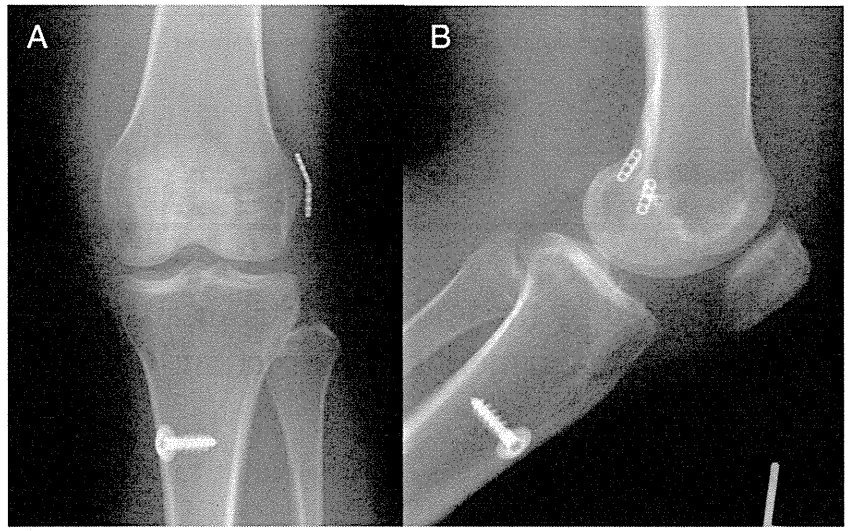

Fig. 1. Anteroposterior (A) and lateral (B) radiographs of Case 1 obtained after anatomic anterior cruciate ligament reconstruction showing two EndoButtons. The EndoButton for the anteromedial bundle was in contact with the lateral femoral cortex, while that for the posterolateral bundle was 1 mm off the surface of the lateral femoral cortex with soft tissue interposition.

band. Irritation of the iliotibial band was eliminated following EndoButton removal, and the patient restarted classical ballet with no lateral knee pain 2 months after surgery.

Case 2. A 35-year-old man complained of chronic right knee instability due to an ACL rupture caused by a trauma during skiing. He underwent arthroscopic anatomic double-bundle ACL reconstruction using hamstring tendons. The surgical procedure was the same as that described in Case 1 (Fig. 3). Three months after surgery, the patient developed moderate pain near the lateral epicondyle in deep knee flexion on the lateral side of his right distal femur. Although this pain did not restrict his activity, it was persistent. Examination of the patient 1 year after surgery using the Lachman test and N-test revealed negative results. Postoperative side-to-side anterior stability measured with the KT-2000 arthrometer was 2.0 mm. The patient experienced tenderness on palpation of the iliotibial band above the EndoButton. The EndoButtons did not migrate, as observed through plane radiographs and computed tomography of the right knee. Since the EndoButtons seemed to be the cause of lateral knee pain, removal of the EndoButtons at the time of planned second-look arthroscopic evaluation was suggested. A second-look arthroscopic evaluation was performed 24 months after the ACL surgery. The arthroscopic findings indicated that the reconstructed ACL revealed excellent results and there was no meniscal or cartilaginous injury. At the second surgery, the iliotibial band was retracted and the two EndoButtons were removed. There was no friction between the lateral structures, except between the iliotibial band and the EndoButtons. Two EndoButtons existed beneath the iliotibial band, which was not scratched but thickened. After the second surgery, the lateral knee pain in deep knee flexion was eliminated, and the patient returned to skiing without any pain 5 months after surgery. Both patients were informed that their data would be submitted for publication, and they gave their consent for the same.

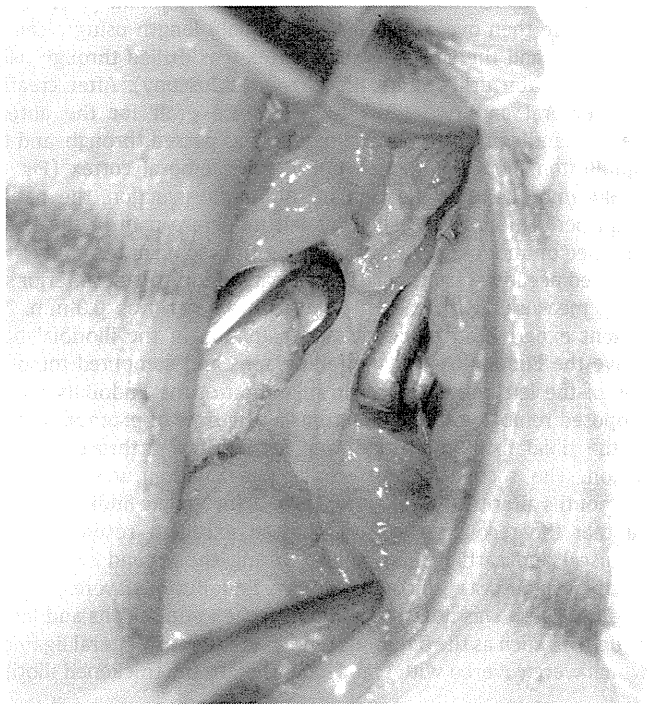

Fig. 2. Surgical image during excision of two EndoButtons under the iliotibial band.

3. Discussion

We describe two patients requiring removal of implants because of lateral knee pain following anatomic double-bundle ACL reconstruction using EndoButtons for femoral fixation. Both patients were completely asymptomatic several months after implant removal, implying that the EndoButtons caused the mechanical irritation of the iliotibial band. Although the presence of iliotibial band friction syndrome caused by use of transfemoral fixation devices has been reported, that caused by a suspension device such as the EndoButton has not been reported previously [14–16]. To the best of our knowledge, this is the first report describing removal of EndoButtons because of pain caused by irritation of the iliotibial band. During the past 6 years, we performed anatomic double-bundle ACL reconstruction for 142 patients. Iliotibial band friction syndrome caused by the EndoButton occurred in 1.4% (two of 142 patients) of patients undergoing the procedure, and this is a relatively rare phenomenon.

In both cases reported herein, the Endobutton was placed near the lateral epicondyle (Fig. 4). A small bulge of the EndoButton on the lateral epicondyle under the iliotibial band seemed to be the cause of friction syndrome. The posterolateral tunnel in anatomic ACL reconstruction involved a theoretical risk of iatrogenic lesion of lateral structures such as the lateral collateral ligament, lateral gastrocnemius tendon, or popliteus tendon [17]. Most literature lacks reference to

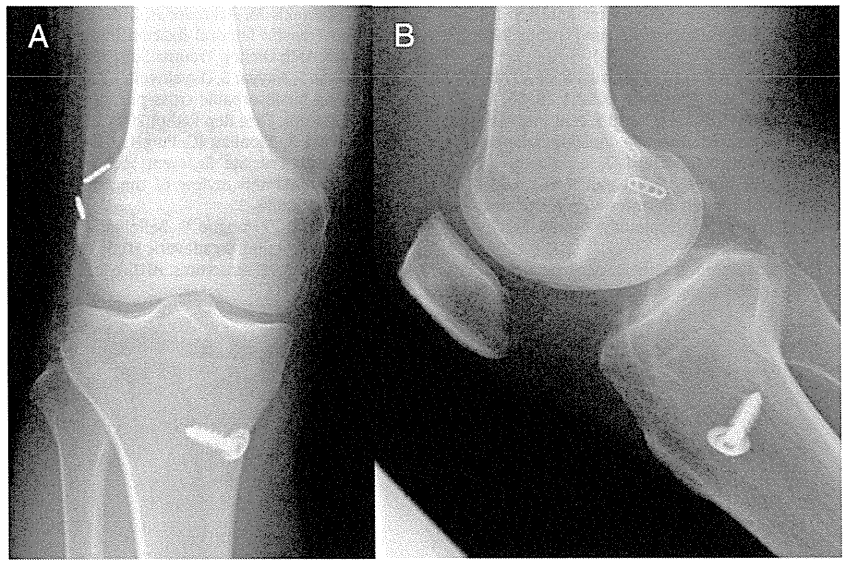

Fig. 3. Anteroposterior (A) and lateral (B) radiographs of Case 2 obtained after anatomic anterior cruciate ligament reconstruction showed two EndoButtons. The EndoButtons were in contact with the lateral femoral cortex.

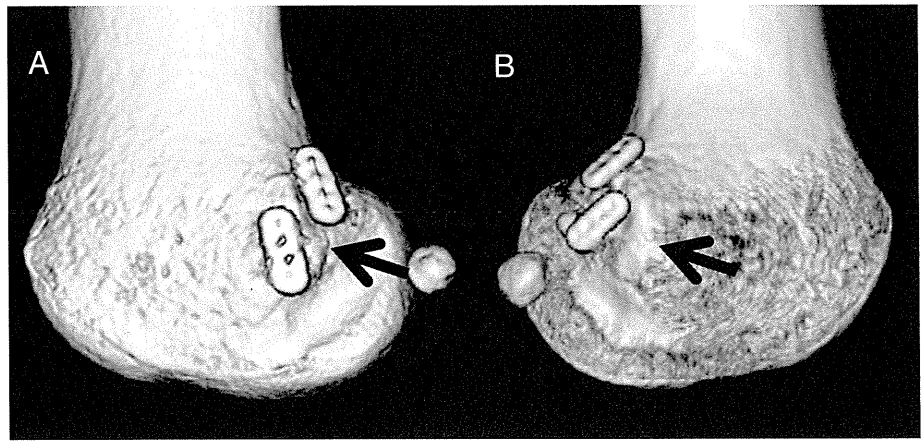

Fig. 4. Postoperative three-dimensional computed tomography of Case 1 (A) and Case 2 (B): Each Endobutton for the posterolateral bundle was placed near the lateral epicondyle in both cases. Black arrows showed the lateral epicondyle of the distal femur.

the possibility of iliotibial band friction of the femoral suspension device. If the femoral tunnel exit is positioned near the lateral femoral epicondyle in anatomic ACL reconstruction, care must be taken to prevent iliotibial band friction syndrome that could result from the EndoButton. Use of an image intensifier or a navigation system can avoid iliotibial band friction in cases where femoral tunnels are created through a far anteromedial portal. Otherwise, though additional incisions are required, the femoral tunnels should be created using the outside-in technique, taking care not to place the femoral tunnel exits near the lateral epicondyle of the femur. We believe that these case reports may result in improvements in anatomic ACL reconstruction using EndoButtons as femoral fixation devices.

Conflict of interest

The authors declare that they have no conflict of interest associated with this manuscript and there has been no significant financial support for this work that could have influenced its outcome.

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Clinical outcome of anatomic double-bundle ACL reconstruction and 3D CT model-based validation of femoral socket aperture position

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Abstract
Purpose The purpose of this study was to evaluate the clinical results of anatomic double-bundle (DB) anterior cruciate ligament (ACL) reconstruction in which anatomic position of femoral socket apertures was validated using three-dimensional (3D) computed tomography (CT) modelling.
Methods Anatomic DB ACL reconstructions with hamstring autografts were performed in 34 patients. Two femoral sockets were created through a far anteromedial (AM) portal behind the lateral intercondylar ridge with the assistance of intraoperative 3D fluoroscopic navigation. Femoral tunnel aperture positioning was investigated postoperatively using 3D CT images in all patients. Clinical results were also evaluated subjectively and objectively at least up to 2 years.
Results Measurement of the AM and the posterolateral (PL) femoral socket locations on the 3D CT images using the quadrant method showed that the centre of the AM socket aperture was located at a depth of 21.0 ± 4.1 % and a height of 30.5 ± 9.3 % and that of the PL socket aperture was located at a depth of 31.3 ± 5.8 % and a height of 57.2 ± 7.7 %. The femoral socket locations were considered as anatomic in accordance with previous cadaveric studies examining the positions of ACL femoral insertion site. Subjectively, the mean Lysholm score was 96.9 ± 4.0 points. According to IKDC final objective scores, 26 knees (76 %) were objectively graded as normal, 8 (24 %) as nearly normal, and 0 (0 %) as abnormal or severely abnormal. Postoperative side-to-side anterior translation measured with a KT-2000 arthrometer averaged 0.7 ± 1.2 mm.
Conclusions DB ACL reconstructions in which femoral socket apertures were validated anatomically using 3D CT provided satisfactory short-term results.
Level of evidence Case series, Level IV.

Keywords Navigation · Femoral tunnel · Anterior cruciate ligament reconstruction · Three-dimensional computed tomography · Double-bundle · Anatomic

Introduction

The aims of anterior cruciate ligament (ACL) reconstruction are to mimic the natural anatomy of the native ACL and restoration of natural knee kinematics. Recent studies have contributed to a better understanding of ACL anatomy and have led to "anatomic" ACL reconstruction. It is widely accepted that the ACL consists of two functional bundles: anteromedial (AM) and posterolateral (PL) [2, 3]. On the femur, the ACL attaches to the posterosuperior aspect of the lateral wall of the intercondylar notch [8, 14]. When the knee is flexed at 90° under arthroscopic observation, the lateral intercondylar ridge is the superior border of ACL [31], and the lateral bifurcate ridge separates the AM and PL insertion sites [10]. During anatomic ACL reconstruction, these bony anatomical features are important topographic landmarks by which to identify the two-bundle femoral attachment of the ACL [39, 40]. In theory, graft placed at native insertion sites, especially the femoral

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site, could improve the restoration of knee stability and superior clinical outcomes [25, 29]. However, there is no clinical consensus regarding appropriate tunnel position in anatomic ACL reconstruction. To arrive at such a consensus, it is necessary to confirm whether the tunnels are placed in the true anatomic position after the so-called anatomic ACL reconstruction. Although there have been many reports in the literature describing the clinical results of "anatomic" double-bundle (DB) ACL reconstruction, most lack morphometric analysis of anatomic tunnel locations after the operation [1, 19, 24, 32, 37, 41, 44].

Recently, several authors have used three-dimensional (3D) computed tomography (CT) scan images to describe native ACL insertion [4] or to evaluate tunnel positions [6, 11, 20, 21, 34]. CT images are recommended instead of plain radiographs for the postoperative evaluation of tunnel positions in ACL reconstruction [15]. A 3D CT scan model quadrant method has been reported as reliable to measure the location of the femoral tunnels following ACL reconstruction [22]. Therefore, the purpose of this study was to present the short-term clinical outcome of anatomic DB ACL reconstruction with hamstring tendon autografts, as well as to show the quantitative locations of the femoral socket apertures using the postoperative 3D CT model. It was hypothesised that the results after DB ACL reconstruction, in which two femoral socket apertures were validated as anatomic, would be satisfactory.

Materials and methods

Of the 77 consecutive patients on whom ACL reconstruction was performed at our institute between 2008 and 2010, 44 met the study inclusion criteria. These criteria were as follows: (1) using autologous hamstring grafts for DB ACL reconstruction, (2) no prior intra-articular or extra-articular ligament reconstruction, (3) no history of ligament injury of the contralateral knee, (4) absence of posterior sagging, abnormal varus/valgus instability, and (5) undergoing outpatient rehabilitation at our institute. An experienced surgeon (T.N.) participated in all surgeries as an operator or a first assistant. Although 10 patients were lost to follow-up, 34 (77 %) were available for follow-up at least 24 months after the operation. The clinical and radiographical data of these 34 patients were evaluated retrospectively. These patients included 10 females and 24 males with a median age of 31 years (range 16–63 years) at time of surgery. The median follow-up period was 26 months (range 24–40 months). Patient information is summarised in Table 1. The institutional review board approved this retrospective study. Patients and their families were informed that data from their cases would be submitted for publication, and all provided consent.

Table 1 Preoperative patient information

Number of patients	34
Gender (female/male)	10/24
Age (years)	31 (16–63)
Body height (cm)	169 ± 9
Body weight (kg)	67 ± 16
Body mass index (kg/m^2)	23.1 ± 3.8
Time between injury and surgery (months)	5 (1–300)
Follow-up period (months)	26 (24–40)
Tegner activity scale	6 (5–9)

Data are given as means ± standard deviations or medians (range)

Surgical procedure

ACL reconstruction was arthroscopically performed using a 3D fluoroscopy-based navigation system to place the two femoral tunnels, as described previously [26]. Briefly, the hamstring tendons were harvested, and the doubled grafts were looped over EndoButton CLs (Smith & Nephew Endoscopy, Andover, MA, USA). The semitendinosus tendon was transversely cut into two portions, and each portion was looped. When the graft was <5 mm in diameter, the gracilis tendon was also harvested. The distal free ends of the grafts were armed with No. 3 Ethibond sutures using a whip-stitch technique. The femoral insertion site for each bundle was determined while monitoring the bony landmarks [10, 12] (i.e. the lateral intercondylar ridge and the lateral bifurcate ridge) by arthroscopic view and on the navigation screen (StealthStation TRIA^{TM} *plus*, Medtronic, Louisville, CO, USA). The priority for creating the femoral sockets was to position the femoral socket apertures within the femoral footprint of the ACL. Keeping the knee in a deep flexion, two guidewires for the femoral tunnels were placed through a far AM portal [30] while referencing the navigation computer screen (Fig. 1). The wires were then overdrilled for an adequate length using a cannulated drill, and the lateral femoral cortex was drilled through using an EndoButton drill (Smith & Nephew Endoscopy). On the tibial side, two guidewires were positioned and overdrilled for the full length by a cannulated drill. The tibial insertion site was arthroscopically determined in reference to the ACL remnant, the medial tibial eminence, the anterior horn of the lateral meniscus, the intermeniscal ligament, and the posterior cruciate ligament [9]. The tibial tunnels were placed in the centre of the AM and PL footprints. After creating two femoral sockets and two tibial tunnels, both grafts were passed through, and the EndoButton loop was flipped outside of the femoral cortex in the usual manner. The grafts were preconditioned 10 cycles with maximum manual tension. Tibial fixation of the hamstring autografts was accomplished over a suture post fixation with a fully threaded 6.5-mm cancellous screw and washer (Meira Co,

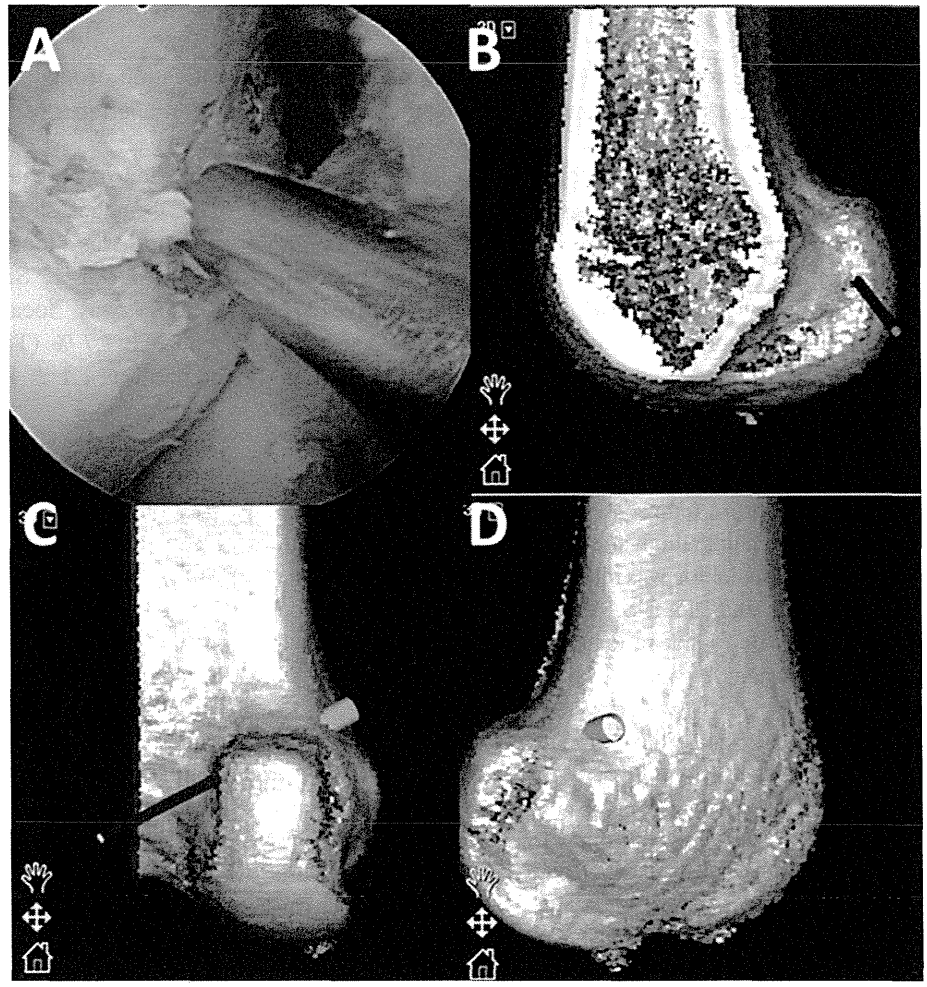

Fig. 1 **a** The tip of the femoral guide was placed at the centre of the posterolateral (PL) bundle femoral footprint on arthroscopy. **b** An *arrow* pointing to the tip of the femoral guide placed at the centre of the PL bundle on the 3D reconstructed image. **c** A virtual tunnel in the 3D femoral image without breakage of the posterior cortex on the navigation monitor. **d** The exit site of the virtual femoral tunnel shown on the lateral cortex of the 3D image

Nagoya, Japan). The AM bundle graft was fixed at 60° knee flexion, and the PL bundle was fixed at full knee extension with maximum manual tension.

Postoperative rehabilitation

The knee was not immobilised but was protected for 5 weeks with a functional brace. Active and assisted range of motion exercises were started immediately after the surgery. Partial weight-bearing was allowed at 2 days, and full weight-bearing was started at 1 week. Running was allowed at 4 months followed by return to previous sporting activity at 8–9 months on average.

Morphometric evaluation of the femoral sockets postoperatively

A CT scan of the operated knee was performed a week after surgery for all patients, using a helical high-speed Aquilion^{TM} 64 or Aquilion ONE^{TM} (Toshiba Medical Systems Co., Japan) CT machine. The ZIOSTATION software package (Ziosoft Inc., Tokyo, Japan) was used for 3D reconstruction of the operated knee. The tibia, the patella, and the medial femoral condyle were removed as necessary to visualise the lateral wall of the intercondylar notch. All measurements were made on a 3D CT view of the lateral wall of the intercondylar notch in the sagittal plane. Morphometric assessment of the femoral socket positioning of the AM and the PL bundles was performed according to the quadrant technique as described by Bernard and Hertel [5]. The total sagittal diameter of the lateral condyle along Blumensaat's line (*D*) and maximum lateral intercondylar notch height (*H*) were measured on the 3D CT scan image (Fig. 2). The distance from the centre of the AM or the PL socket aperture to the most dorsal subchondral contour of the lateral femoral condyle (*d*) and the distance from the centre of each socket to Blumensaat's line (*h*) were measured. The length of distance (*d*) as a partial distance of (*D*) and the height of the distance (*h*) as a partial distance of (*H*) were expressed in percentages, such as *d*/*D* % and *h*/*H* %, respectively. All measurements were performed by an orthopaedic surgeon (S.T.) and were repeated at 3-month intervals.

Clinical evaluation

All patients were subjectively evaluated using the Lysholm score [23]. The International Knee Documentation Committee (IKDC) Knee Examination Form 2000 was used for objective evaluations [17]. In addition to the IKDC score, the Lachman test was graded as negative (<2 mm), trace (3–5 mm), or positive (>6 mm). Also, the *N* test, which is similar to reverse pivot shift test and used to determine rotational stability, was graded as negative, glide, or positive [27]. Anterior knee stability was quantitatively assessed using a KT-2000 arthrometer (MEDmetric Corp. San Diego, CA, USA). Reconstructed and contralateral knees were measured with a 134-N anterior force applied to the proximal tibia at 20° of knee flexion. The side-to-side difference in anterior translation was used as a representative indicator of restored knee stability. To evaluate thigh strength, the peak torque strength in extension and flexion was measured using Cybex® (Lumex, Inc., Ronkonkoma, NY, USA) during concentric contraction at 60°/s. The side-to-side ratio in peak muscle torque was used as the representative parameter for thigh muscle strength.

Statistical analysis

Statistical analysis was performed using the EXCEL statistics 2012 software package for Microsoft Windows (SSRI Co., Ltd., Tokyo, Japan). Clinical outcomes were compared with Student's *t*-test and the chi square test. The statistical significance level was set at $P < 0.05$. Data in text are given as means ± standard deviations.

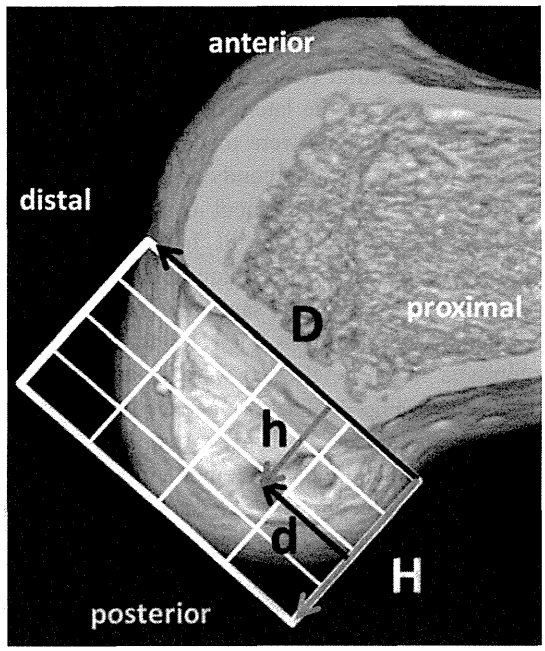

Fig. 2 Measurements of femoral socket positioning using the quadrant method described by Bernard and Hertel [5]

Results

Validation of anatomical placement of the femoral socket apertures using the postoperative CT model

The mean of repeated measurements on the postoperative 3D CT images showed that the centre of the AM socket aperture was located at *d*/*D* 21.0 ± 4.1 % and *h*/*H* 30.5 ± 9.3 %. Similarly, the centre of the PL socket aperture was located at *d*/*D* 31.3 ± 5.8 % and *h*/*H* 57.2 ± 7.7 % (Table 2; Fig. 3). The intraobserver difference was 1.1 ± 1.5 %.

Clinical results

The clinical results are shown in Table 3. The postoperative mean Lysholm score was 96.9 ± 4.0 points, which was significantly better than the preoperative score ($P < 0.001$). With respect to the range of motion of the knee, loss of extension and loss of flexion compared with the contralateral knee >5° were observed in one patient. This patient had arthroscopic mobilisation 6 months after primary surgery and regained almost full range of motion of the affected knee and subsequently returned to sports without any complaints. The Lachman test of the operated knee was negative in 31 patients (91 %) and trace in three patients (9 %). The postoperative side-to-side difference in anterior translation measured with the KT-2000 arthrometer averaged 0.7 ± 1.2 mm, with 30 patients (88 %) having a range between −1 and 2 mm. The postoperative *N* test was negative or glide in all patients (100 %). Both anteroposterior stability, as evaluated by the Lachman test or KT-2000, and rotational stability, as evaluated by the *N* test, were significantly better after surgery ($P < 0.001$). The IKDC final score was normal in 26 patients (76 %) and nearly normal in 8 (24 %). No patients were graded as abnormal or severely abnormal. Regarding the isokinetic peak torque of knee extension and flexion, the mean ratio of the operated knee compared with the contralateral side was 85 ± 15 and 92 ± 13 %, respectively. There were no instances of postoperative infection or rerupture in this series. One patient complained of moderate knee pain 30 months after primary ACL reconstruction. A second-look arthroscopy revealed no healing of the sutured medial meniscus, and thus, a partial meniscectomy was performed.

Discussion

The most important finding of the study was that morphometric analysis of femoral socket placement on postoperative 3D CT images using the quadrant method [5] in this study revealed anatomic femoral socket placements

Table 2 Centre of the AM and the PL socket location on 3D computed tomography

	AM bundle		PL bundle	
	d/D (%)	*h/H* (%)	*d/D* (%)	*h/H* (%)
Current clinical data	21.0 ± 4.1	30.5 ± 9.3	31.3 ± 5.8	57.2 ± 7.7
Cadaveric study (Forsythe et al. [11])	21.7	33.2	35.1	55.3
Cadaveric study (Iriuchishima et al. [16])	15	26	32	52
Cadaveric study (Zantop et al. [43])	18.5	22.3	29.3	53.6

d/D (%) = depth of Blumensaat's line from deepest subchondral contour

h/H (%) = height of the lateral femoral condyle from Blumensaat's line

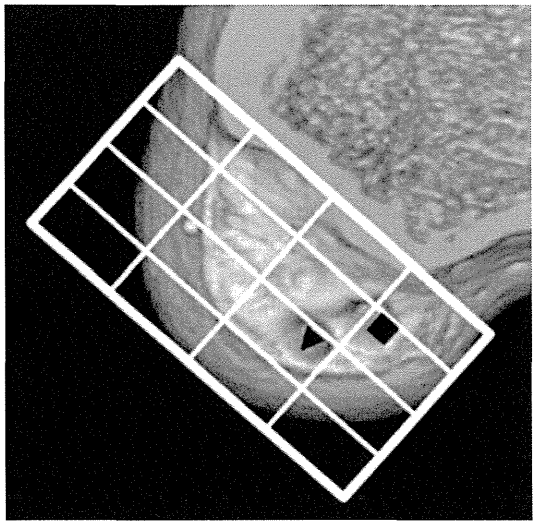

Fig. 3 Centre of the anteromedial (AM) and the posterolateral (PL) socket location calculated using the quadrant method in the current study. The *black square* shows the location of the centre of the AM socket, and the *black triangle* shows the location of the PL socket

which were very similar to cadaveric data previously reported (Table 2) [11, 16, 43]. Recently, computer-assisted surgery has been introduced to improve the accuracy and reproducibility of socket placement in ACL reconstruction [7, 18, 33, 36]. We have used a 3D fluoroscopy-based navigation system to place two femoral sockets accurately and reproducibly through a far AM portal [26]. Surgeons can identify the lateral intercondylar ridge which is an important landmark for ACL femoral insertion not only arthroscopically but also on 3D images using this navigation system for DB ACL reconstruction. On the basis of this study, it can be said that femoral sockets can be anatomically and reproducibly created using 3D imaging-based navigation.

Although there have been many reports in the literature describing the clinical results of DB ACL reconstruction, few have described simultaneous morphometric evaluation of the femoral tunnel apertures. Previous biomechanical studies indicated that stability of the knee after ACL reconstruction would be influenced by tunnel position,

Table 3 Clinical results

	Before surgery	At final follow-up	*P* value
Lysholm score (points)	74.1 ± 10.7	96.9 ± 4.0	<0.001
Loss of extension (>5°)	0 (0 %)	1 (3 %)	
Loss of flexion (>5°)	4 (12 %)	1 (3 %)	
Lachman test			
Negative	0	31	<0.001
Trace	3	3	
Positive	31	0	
N test			
Negative	0	30	<0.001
Glide	4	4	
Positive	30	0	
IKDC2000			
A: normal	0	26	<0.001
B: nearly normal	0	8	
C: abnormal	23	0	
D: severely abnormal	11	0	
Side-to-side deference with KT-2000 arthrometer (mm)	3.9 ± 1.7	0.7 ± 1.2	<0.001
Side-to-side ratio of isokinetic peak torque of knee extension (at 1 year)	N/A	85 ± 15 (%)	
Side-to-side ratio of isokinetic peak torque of knee flexion (at 1 year)	N/A	92 ± 13 (%)	

Data are given as means ± standard deviations

IKDC International Knee Documentation Committee, *N/A* no assessment

especially that of the femoral sockets. According to a cadaveric biomechanical study described by Zantop et al. [42], nonanatomical DB ACL reconstruction did not restore normal knee kinematics while anatomical DB reconstruction did. On the basis of this data, it is essential to locate the bone tunnel anatomically for better restoration of native ACL function. Tsuda et al. [38] reported the relationship between the tunnel positions using the quadrant method and the results of postoperative knee stability

Table 4 Literature review

Authors	Number of patients	Lysholm score	IKDC objective final score	KT value (mm) side-to-side difference	Rotational stability
Aglietti et al. [1]	25	N/A	A: 76 % B: 20 % C: 4 % D: 0 %	1.4 (134 N)	84 % negative (pivot shift)
Kondo et al. [19]	171	97.3	A: 64 % B: 31 % C: 5 % D: 0 %	1.2 (133 N)	81 % negative (pivot shift)
Muneta et al. [24]	34	94.5	N/A	1.4 (manual max)	85 % negative (pivot shift)
Siebold et al. [32]	35	90	A: 78 % B: 19 % C: 0 % D: 3 %	1.0 (134 N)	97 % negative (pivot shift)
Toritsuka et al. [37]	75	N/A	N/A	0.9 (manual max)	97 % negative (pivot shift)
Yagi et al. [41]	20	N/A	A: 85 % B: 10 % C: 5 % D: 0 %	1.3	85 % negative (pivot shift)
Zhao et al. [44].	43	94.1	A + B: 97.7 % C + D: 2.3 %	1.1 (134 N)	95 % negative (pivot shift)
Current study	34	96.9	A: 76 % B: 24 % C: 0 % D: 0 %	0.7 (134 N)	88 % negative (*N* test)

IKDC International Knee Documentation Committee, *N/A* not available

examinations. They concluded that the variability of the femoral tunnel position was not so large as to result in postoperative knee laxity in their series. The clinical results of ACL reconstruction in this study that achieved radiographic concordance of femoral socket placement with cadaveric studies were excellent both subjectively and objectively. When these clinical results were compared with those described in the literature after DB ACL reconstruction using hamstring tendons [1, 19, 24, 32, 37, 41, 44] (Table 4), both the subjective assessment and the objective assessment of this series were comparable. In particular, with regard to the KT-2000 side-to-side difference, our results were superior to those of others (Table 4). These clinical data are thought to support the previous biomechanical studies that anatomical tunnel placement is essential to yield knee stability without graft impingement in ACL reconstruction. This is the first study to determine both clinical outcomes and validate aperture positioning in patients, as opposed to recent cadaveric studies. It is considered that there is not enough evidence to support validated tunnels improve outcome at the moment, but rather, it is a very important first step towards improved outcome, and using postoperative CT evaluation, surgeons can obviously exclude malpositioned tunnels as a reason for failed ACL reconstruction. We believe that postsurgical validation of position of tunnel apertures (whether reconstruction is anatomic, single/double-bundle, etc.) will allow more rigorous comparisons of different surgical approaches with clinical outcomes.

There were some limitations to this study. The first is that the follow-up period was relatively short. Long-term results are needed to answer the questions of whether anatomic DB ACL reconstruction will better protect the menisci and prevent the onset and progression of osteoarthritis of the knee and whether it will decrease the rate of revision surgeries. The second limitation was that this was a retrospective study with a relatively small number of patients. The third limitation was absence of a control group. Comparison with the results of ACL reconstruction using other grafts such as bone-patellar tendon-bone grafts with guidance of the navigation system or the result of DB ACL reconstruction using hamstring tendon grafts without the navigation system would increase the power of this study. The fourth limitation is that quantitative measurements of the pivot shift phenomenon or knee function during sporting activities after ACL reconstruction are limited. Though rotational instability is usually examined by manual tests such as the pivot shift test or *N* test, they are neither quantitative nor objective [13, 27]. Although several studies have reported laboratory tests to measure the kinematics of ACL-reconstructed knees, currently some problems, including costs, accuracy, and invasiveness, remain [28, 35]. The fifth limitation is that the tibial tunnel placement was not evaluated in current study. While the ACL tibial remnant, the intermeniscal transverse ligament, the posterior cruciate ligament, and the anterior horn of lateral meniscus were took as landmarks for placement of the tibial tunnels, and the navigation system was used for femoral socket creation. Therefore, only the femoral socket placement was evaluated in the current series.

Conclusions

DB ACL reconstruction, in which femoral tunnel apertures were confirmed as anatomic on postoperative 3D CT imaging, yielded favourable clinical results.

Conflict of interest The authors declare that they have no conflict of interest.

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Impact of Hospital Volume on Postoperative Complications and In-Hospital Mortality After Musculoskeletal Tumor Surgery

Analysis of a National Administrative Database

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Background: We are aware of only one report describing the relationship between operative volume and outcomes in musculoskeletal tumor surgery, although numerous studies have described such relationships in other surgical procedures. The aim of the present study was to use a nationally representative inpatient database to evaluate the impact of hospital volume on the rates of postoperative complications and in-hospital mortality after musculoskeletal tumor surgery.

Methods: We used the Japanese Diagnostic Procedure Combination administrative database to retrospectively identify 4803 patients who had undergone musculoskeletal tumor surgery during 2007 to 2010. Patients were then divided into tertiles of approximately equal size on the basis of the annual hospital volume (number of patients undergoing musculoskeletal tumor surgery): low, twelve or fewer cases/year; medium, thirteen to thirty-one cases/year; and high, thirty-two or more cases/year. Logistic regression analyses were performed to examine the relationships between various factors and the rates of postoperative complications and in-hospital mortality adjusted for all patient demographic characteristics.

Results: The overall postoperative complication rate was 7.2% (348 of 4803), and the in-hospital mortality rate was 2.4% (116 of 4803). Postoperative complications included surgical site infections in 132 patients (2.7%), cardiac events in sixty-four (1.3%), respiratory complications in fifty-one (1.1%), sepsis in thirty-one (0.6%), pulmonary emboli in sixteen (0.3%), acute renal failure in eleven (0.2%), and cerebrovascular events in seven (0.1%). The postoperative complication rate was related to the duration of anesthesia (odds ratio [OR] for a duration of more than 240 compared with less than 120 minutes, 2.44; 95% confidence interval [CI], 1.68 to 3.53; $p < 0.001$) and to hospital volume (OR for high compared with low volume, 0.73; 95% CI, 0.55 to 0.96; $p = 0.027$). The mortality rate was related to the diagnosis (OR for a metastatic compared with a primary bone tumor, 3.67; 95% CI, 1.66 to 8.09; $p = 0.001$), type of surgery (OR for amputation compared with soft-tissue tumor resection without prosthetic reconstruction, 3.81; 95% CI, 1.42 to 10.20; $p = 0.008$), and hospital volume (OR for high compared with low volume, 0.26; 95% CI, 0.14 to 0.50; $p < 0.001$).

Conclusions: We identified an independent effect of hospital volume on outcomes after adjusting for patient demographic characteristics. We recommend regionalization of musculoskeletal tumor surgery to high-volume hospitals in an attempt to improve patient outcomes.

Level of Evidence: Prognostic Level II. See Instructions for Authors for a complete description of levels of evidence.

Since Luft et al. demonstrated a relationship between operative volume and surgical outcomes in 1979[1], numerous studies have demonstrated associations between higher operative volume and better patient outcomes for various surgical procedures, including renal surgery, lobectomy for lung cancer, and laparoscopic colectomy[2-4]. An association between

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higher operative volume and better outcomes has also been suggested in orthopaedic surgery, including surgery involving trauma, joint replacement, and the spine[5-9].

It is widely recognized that patients undergoing musculoskeletal tumor surgery are at increased risk of postoperative complications and in-hospital mortality, compared with patients undergoing general orthopaedic surgery, because of the more invasive nature of the surgical procedures and the generally poorer condition of patients who have undergone preoperative chemotherapy. To date, postoperative complications of musculoskeletal tumor surgery, such as surgical site infection or venous thromboembolism, have been reported on the basis of limited data from single centers or a few major referral centers[10-15]. To our knowledge, the current literature includes no reports describing overall nationwide rates of postoperative complications and in-hospital mortality following musculoskeletal tumor surgery. We are aware of only one study evaluating the relationship between hospital volume and postoperative complication rates[16] and no studies evaluating the relationship between hospital volume and the rate of in-hospital mortality after musculoskeletal tumor surgery.

Given the rarity of musculoskeletal tumors and the specialized surgical procedures required to treat them, we hypothesized that higher hospital volume would be associated with lower rates of postoperative complications and in-hospital mortality. We therefore evaluated the impact of hospital volume on the rates of postoperative complications and in-hospital mortality after musculoskeletal tumor surgery, after adjusting for patient demographic characteristics, by analyzing data from the Diagnostic Procedure Combination (DPC) Database, a nationally representative inpatient database in Japan.

Materials and Methods

DPC Database

The DPC is a case-mix system, which is a classification system similar to the diagnosis-related groups used by Medicare in the United States. This patient classification system was launched in 2002 by the Ministry of Health, Labour and Welfare of Japan and linked to a lump-sum payment system. All eighty-two university teaching hospitals are obligated to adopt the DPC system, but adoption by community hospitals is voluntary. DPC hospitals are surveyed during the second half of each year by the DPC Research Group in collaboration with the Ministry of Health, Labour and Welfare. Administrative claims data and detailed patient data are collected for all inpatients discharged from the participating hospitals from July 1 to December 31. The surveying began in 2003 with eighty-two teaching hospitals, and the number of participating hospitals had increased to 952 in 2010. The numbers of patients included in the survey in 2010 was 3.19 million, representing approximately 45% of all inpatient admissions to acute-care hospitals in Japan.

All of the data for each patient are recorded at discharge and are compiled in the database server at the Department of Health Management and Policy of The University of Tokyo. The data for each patient include the hospital location and patient age, sex, diagnoses and comorbidities at admission, complications after admission (recorded as Japanese-language text data and ICD-10 [International Classification of Diseases, Tenth Revision] codes), procedures (recorded as Japanese-language procedure codes), drugs and devices used, duration of hospital stay, and discharge status.

The DPC database is somewhat similar to the Nationwide Inpatient Sample in the United States[17], but it has several unique advantages. In the DPC database, complications that occurred after admission are clearly differentiated from comorbidities that were already present at admission. To optimize the accuracy of the recorded diagnoses, the physician in charge is obligated to record the diagnoses with reference to the patient's medical charts. All diagnoses and comorbidities are recorded in the DPC database at discharge. Medical clerks and licensed medical information managers accurately record the dates of all major and minor procedures, drug administration, and device use. Physicians and hospitals have a strong incentive for data entry compliance because compliance is mandatory to obtain the DPC-based reimbursement of medical fees.

Study approval was obtained from the institutional review board of The University of Tokyo. Because of the anonymous nature of the data, the requirement for informed patient consent was waived.

Data Extraction

The records of all patients in the DPC database who underwent musculoskeletal tumor surgery during 2007 to 2010 were identified. For each patient, the following data were extracted: sex, age, primary diagnosis, type of surgery, duration of anesthesia, and comorbidities that may have affected the rates of postoperative complications or in-hospital mortality. The comorbidities including diabetes mellitus (ICD-10 codes E10.x-E14.x), chronic lung disease (I27.8, I27.9, J40.x-J47.x, J60.x-J67.x, J68.4, J70.1, J70.3), cardiac disease (I25.2, I09.9, I11.0, I13.0, I13.2, I20.x, I21.x, I22.x, I25.5, I42.0, I42.5-I42.9, I43.x, I50.x, P29.0), cerebrovascular disease (G45.x, G46.x, H34.0, I60.x-I69.x), chronic renal failure (N18.x), and liver disease (I85.0, I85.9, I86.4, I98.2, K70.4, K71.1, K72.1, K72.9, K76.5, K76.6, K76.7). Three categories were utilized for the diagnosis: primary malignant bone tumor (ICD-10 codes C40.x, C41.x), primary malignant soft-tissue tumor (C47.x, C48.0, C49.x), or metastatic bone tumor (C795). Four categories were utilized for the surgery type: bone tumor resection without prosthetic reconstruction, soft-tissue tumor resection without prosthetic reconstruction, bone or soft-tissue tumor resection with prosthetic reconstruction, or amputation. The DPC data do not include information on operative time, but the duration of anesthesia generally reflects operative time. Three categories were utilized for the duration of anesthesia: less than 120 minutes, 120 to 240 minutes, or more than 240 minutes. Each hospital's volume of musculoskeletal tumor surgery was determined with use of its unique hospital identifier and was categorized as low, medium, or high volume. Patients were divided into tertiles of approximately equal sizes on the basis of the annual hospital volume (number of patients undergoing musculoskeletal tumor surgery): low, twelve or fewer cases/year; medium, thirteen to thirty-one cases/year; or high, thirty-two or more cases/year.

End Points

The primary end points were (1) the in-hospital mortality rate, and (2) the postoperative rate of complications including surgical site infections (ICD-10 code T81.3), sepsis (A40.x, A41.x), pulmonary emboli (I26.x), cardiac events (I20.x, I21.x, I50.x), respiratory complications (J10.x-J18.x, J95.2, J96.0), cerebrovascular events (I60.x-I64.x), and acute renal failure (N17.x).

Statistical Analyses

Univariate comparisons of proportions were performed with use of the chi-square test, and comparisons of means were performed with use of analysis of variance. Logistic regression analyses were performed to examine the relationships of each factor with the rates of postoperative complications and in-hospital mortality. Differences were considered to be significant at the $p < 0.1$ level in the univariate analyses and $p < 0.05$ in the multivariate analyses.

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