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Clinical outcome of Niigata-Senami-Kyocera modular unconstrained total elbow arthroplasty for destructive elbow in patients with rheumatoid arthritis

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Background: Total elbow arthroplasty (TEA) is a treatment option for destructive and painful unstable elbows in rheumatoid arthritis (RA). We evaluated the clinical outcomes of unconstrained TEA (Niigata-Senami-Kyocera modular system).
Methods: Seventy-five unconstrained TEAs were performed in patients with RA (mean age, 64 years; age range, 41-79 years; follow-up rate, 97%). Outcome measures included the Japanese Orthopaedic Association (JOA) functional evaluation score for the elbow joint (JOA score), range of motion, and arc. Bone ingrowth of the humeral component, the incidence of stress shielding around the humeral component, the incidence of loosening of the ulnar component, complications, and the survival rate were investigated.
Results: The mean follow-up period was 5.2 years (range, 2-11.3 years). The JOA elbow score improved from 42 points preoperatively to 87 points postoperatively ($P < .0001$). Each specified item improved ($P < .0001$). Flexion improved from 109° to 134°; the flexion-plus-extension arc improved from 70° to 108° ($P < .0001$). Bone ingrowth of the humeral implant was achieved in all elbows. Stress shielding of the humeral component was detected in 11 elbows (14%); it was significantly higher in 10- and 9-mm-diameter humeral stems than in 8-mm-diameter humeral stems ($P = .008$). The ulnar component showed no loosening except in 1 elbow owing to infection. Complications were detected in 9 patients (9 elbows, 12%): periprosthetic infection (3), fracture (4), and dislocation (2). The survival rates were 97% at 5 years and 93% at 10 years postoperatively.
Discussion: The Niigata-Senami-Kyocera modular system for patients with RA showed good outcomes. Stress shielding can be avoided by using an 8-mm-diameter humeral stem.

This study was approved by the Ethics Committee of Niigata University (protocol identification No. 2017-0377).

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The elbow joint is involved in between 21% and 53% of patients with rheumatoid arthritis (RA), and total elbow arthroplasty (TEA) is one of the pain-relieving options for treating the destructive elbow in patients with RA.[3,24] The main types of prostheses used are unlinked or semiconstrained hinged prostheses.[13] It is generally known that unlinked implants have not been clinically shown to improve survivorship compared with linked devices.[18] In addition, in a single-facility study, semi-linked TEA (with the Pritchard Mark II [DePuy, Warsaw, IN, USA] or Coonrad-Morrey prosthesis [Zimmer, Warsaw, IN, USA]) had better outcomes than unlinked TEA (with the Pritchard ERS [DePuy, Warsaw, IN, USA] or Kudo type 3 prosthesis) in terms of complication and revision rates.[21]

In our department, we started using the Niigata-Senami-Kyocera (NSK) (Kyocera, Kyoto, Japan) unconstrained type of artificial elbow joint in 1988, and we have used the unconstrained NSK with a modular system (Niigata-Senami-Kyocera modular [MNSK] system [Kyocera, Kyoto, Japan]) since 1998 (Fig. 1).[1] In the NSK system, the humeral component was made of single-crystal alumina, and loosening was a problem.[1,11] The humeral component of the MNSK system is made of a humeral stem and humeral condyle. Both systems are modular. The humeral stem is available in 3 diameters (8, 9, and 10 mm), and the humeral condyle has 2 options (standard and wide type). For the ulnar component, a titanium alloy or all-polyethylene type is used. With the MNSK system, a new problem occurred: stress shielding. Stress shielding is known to occur around rigidly fixed implants in response to diminished mechanical stress.[5] Our previous report about the MNSK system showed that stress shielding was detected in 38% of cases in which a 10-mm-diameter stem was inserted. Thus, 9- or 8-mm-diameter stems were used to prevent the incidence of stress shielding. When an 8-mm-diameter stem was used in 8 elbows, stress shielding never occurred.[1] Since then, we have used an 8-mm-diameter humeral stem. However, the detailed and midterm clinical outcomes of artificial elbow arthroplasty with the MNSK unconstrained type of artificial elbow joint in patients with RA have been unknown. In this study, we investigated the clinical outcomes of artificial elbow arthroplasty with the MNSK system for destructive or unstable painful elbows in patients with RA.

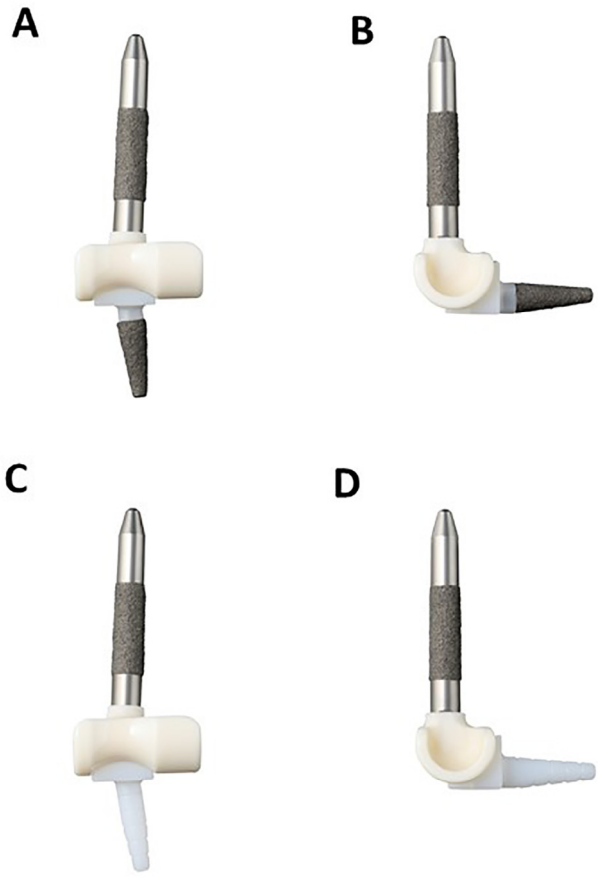

Figure 1 Macroscopic findings of unconstrained total elbow arthroplasty with Niigata-Senami-Kyocera modular system: anteroposterior view **(A, C)** and lateral view **(B, D)**. The humeral component is made of titanium with a porous-coated stem. The humeral condyle component is made of ceramic. The ulnar component is made of 2 types of material: titanium **(A, B)** or all polyethylene **(C, D)**. Both ulnar components are fixed with bone cement. All the photographs show a system with a humeral stem diameter of 8 mm and standard-type humeral condyle component.

Methods

Between 1998 and 2014, 77 TEAs with the MNSK system were performed in 69 patients in our facility. We excluded patients with a Larsen grade V deformity (fork-shaped deformity) because the ulnar component was difficult to place, patients with severe instability due to loosening of the collateral ligaments, patients with infected elbows, and patients with a neuropathic deformity of the elbow. One elbow with osteoarthritis and one elbow in a patient who was lost to follow-up were excluded. Finally, the study subjects included 67 patients (75 elbows) with RA. All patients met the American College of Rheumatology 1987 revised criteria for RA.[2]

Surgical technique

The surgical approach started with the Tsuge technique.[28] The anconeus muscle was preserved, and the lateral collateral ligament was cut and dislocated in maximum passive supination. Then, we detached the soft tissue layer by layer so that the supporting structures,

Figure 2 Representative case in which the Niigata-Senami-Kyocera modular system was used. In a 54-year-old woman with rheumatoid arthritis, preoperative radiographic findings **(A, B)** show a Larsen grade IV deformity. Postoperative radiographic findings are presented in the anteroposterior view **(C)** and lateral view **(D)**. In this case, a humeral stem measuring 8 mm in diameter was used. The humeral condyle was of standard size and was fixed with bone cement. The ulnar component was made of polyethylene and was fixed with bone cement.

such as the medial collateral ligament and triceps tendon, did not loosen. In particular, detachment of the triceps tendon was limited by half of the whole insertion of the olecranon. Thus, the medial collateral ligament was preserved. The width of the radial head was resected 1 to 2 mm to prevent damage to the annular ligament. Synovectomy of the elbow joint was performed as much as possible. We usually repaired the lateral collateral ligament after each permanent component was inserted. In addition, the ulnar nerve was released sufficiently and advanced anteriorly in the subcutaneous tissue.

For the humeral component, cementless fixation was performed for the stem and cement fixation was performed for the condyle. The humeral stem has 3 options for the diameter (8, 9, and 10 mm). The ulnar component is made of a conventional titanium alloy stem and super-high-molecular polyethylene. We have used the all-polyethylene type since July 2005 (Fig. 2).

Regarding the ulnar components, we used the titanium alloy type in 46 elbows and the all-polyethylene type in 29 elbows. Cement fixation was performed for all the ulnar components. After fixation at 2 weeks postoperatively, a long-arm plaster splint was applied and range-of-motion training of the joints was initiated.

Data collection and analysis

The assessment items for the Japanese Orthopaedic Association (JOA) functional evaluation score for the elbow joint (JOA score)[20,26] were used. The evaluation form was prepared to determine the overall elbow function, and overall elbow function was assessed by totaling scores (0-100 points) for each of the following items: pain (0-30 points), function (0-20 points), range of motion (0-30 points), instability (0-10 points), and deformity (0-10 points) of the elbow joint. The higher the score, the better the functional outcomes. Elbow joint range of motion (active flexion, extension, supination, and pronation) was evaluated preoperatively and at the final follow-up. The elbow

functional arc necessary for activities of daily living ranges from 30° to 130°.[25] A systematic review of 9379 TEAs, including linked and unlinked types, showed that the mean range of motion postoperatively was 129° in flexion and –30° in extension.[29] In patients with RA who received the Kudo type 5 elbow prosthesis, in which the humeral component did not have cement fixation, extension worsened from –38° preoperatively to 42° postoperatively and some extension lag remained.[17] Therefore, we defined an extension lag greater than 30° as postoperative flexion contracture and compared it with the preoperative condition.

The flexion-extension arc and supination-pronation arc were also examined. To observe bone ingrowth of the humeral component, the status of spot welds around the humeral component—defined as bone ingrowth in the porous-coated portion that can be detected between the porous-coated part of the humeral stem and endosteum[7]—and the extent and progression of stress shielding—which is indicated by translucency around the component on a plain radiograph—were graded using the Gruen system.[9,23] Lucencies were graded as follows: none, incomplete with less than 2 mm, incomplete with greater than 2 mm, complete with less than 2 mm, and complete with greater than 2 mm. The incidence of stress shielding (Fig. 3) was measured by the stem diameter. We also assessed whether each incidence of stress shielding was progressive radiographically. The sinking and loosening of the ulnar component were assessed radiographically. Complications, such as periprosthetic joint infection, fracture, and dislocation, were also evaluated.

The survival rate was examined by a Kaplan-Meier curve. Revision surgery because of surgical-site infection, fracture, and dislocation was determined as the endpoint.

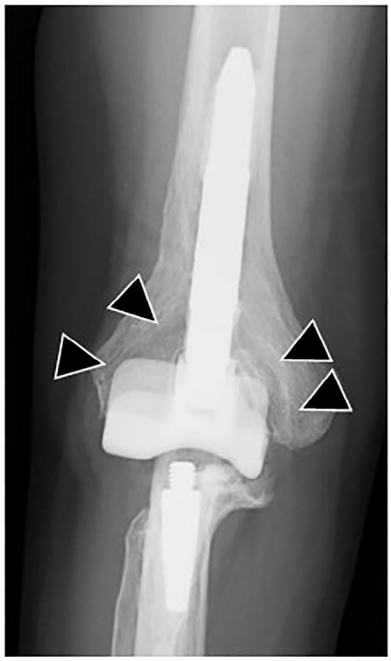

Figure 3 Radiographic findings of the elbow joint in the anteroposterior view showing loosening around the humeral condyle component (*arrowheads*). Loosening is detected on the medial and lateral sides around the humeral condyle component (humeral stem, 10 mm in diameter), and according to the Gruen system, incomplete loosening (>2 mm) is observed. No loosening is detected around the ulnar component.

Statistical analysis

Data were analyzed using the Student *t* test or the χ^2 test. $P < .05$ indicated a statistically significant difference.

Results

The patients' mean age was 64 ± 9.3 years (range, 41-79 years), and 61 patients were women, accounting for 89% of the patients. The duration of RA at the primary surgical procedure of TEA was 17.2 ± 7.9 years on average (range, 1-37.5 years). The mean follow-up duration was 5.2 ± 3.0 years (range, 2-11 years) (Table I). Of the 67 patients (75 elbows), none was lost to follow-up.

Preoperative radiographic findings showed that most cases were Larsen grade IV (67 elbows), followed by Larsen grade III (5) and Larsen grade V (3). Regarding comorbidities, the patients had hypertension (13 cases), osteoporosis (11), diabetes mellitus (4), Sjögren syndrome (2), nontuberculous mycobacteria (2), and hyperlipidemia (2).

Concerning medications, methotrexate was used in 43 patients (64%) at a dose of 6.7 ± 1.7 mg/week on average (range, 4-12 mg/week). Prednisolone was used in 25 patients (40%) at a dose of 6.1 ± 3.0 mg/d on average (range, 2-15 mg/d). Regarding conventional synthetic disease-modifying antirheumatic drugs, salazosulfapyridine was used in 21 patients; bucillamine, 19 patients; D-penicillamine, 3 patients; and tacrolimus, 3 patients. The biological disease-modifying antirheumatic drugs tocilizumab and etanercept were used in 3 cases each (Table I).

JOA score

The JOA score improved significantly from a mean ± standard deviation of 42 ± 10 points preoperatively to 87 ± 9.4 points at the time of examination. Pain improved from 6.8 ± 4.6 points preoperatively to 29.5 ± 1.5 points postoperatively; function improved from 10 ± 3.6 points to 17.5 ± 3.3 points; range of motion improved from 13.5 ± 5.3 points to 21.9 ± 5.1 points; stability improved from 4.1 ± 3.9 points to 9.4 ± 1.8 points; and deformity improved from 7.2 ± 2.0 points to 8.3 ± 1.7 points. Significant improvement was shown in each aforementioned item ($P < .0001$ for all) (Table II).

Elbow joint range of motion

Flexion improved from 109° ± 20° preoperatively to 134° ± 11° postoperatively, and extension improved from –38° ± 16° to –26° ± 15°; both showed significant improvement ($P < .0001$ for both) (Table III). The flexion-plus-extension arc improved from 70° ± 25° to 108° ± 22° ($P < .0001$). The incidence of flexion contracture (defined as more than –30° of extension) significantly decreased from 60% (45 elbows) to 28% (21 elbows) ($P < .0001$) (Table III).

Table I Patients' demographic data

	Data for all patients (67 patients, 75 elbows)	%	Dose
Sex, n			
Female	61	89	
Male	6	11	
RA disease duration at TEA, yr	17.4 ± 8 (1-17)		
Age, yr	64 ± 9 (41-79)		
Follow-up duration, yr	5.2 ± 3 (2-11.3)		
Radiographic classification (Larsen grade), n			
Grade III	5	7	
Grade IV	67	89	
Grade V	3	4	
Medication, n			
MTX	43	64	6.7 ± 1.7 (4-12) mg/week
PSL	27	40	6.1 ± 3.0 (2-15) mg/d
SASP	21	31	
BC	19	28	
D-Pc	3	4.50	
GST	2	3.00	
TAC	2	3.00	
bDMARD, n			
Etanercept	3	4.50	
Tocilizumab	3	4.50	

SD, standard deviation; *RA*, rheumatoid arthritis; *TEA*, total elbow arthroplasty; *MTX*, methotrexate; *PSL*, prednisolone; *SASP*, salazosulfapyridine; *BC*, bucillamine; *D-Pc*, D-penicillamine; *GST*, gold sodium thiomalate; *TAC*, tacrolimus; *bDMARD*, biological disease-modifying antirheumatic drug.
Data are presented as mean ± standard deviation (range [minimum-maximum]) unless otherwise indicated.

Table II Evaluation of preoperative and postoperative JOA functional evaluation scores of elbow joint

Evaluated item	Preoperative	Postoperative	*P* value
JOA score	42 ± 10 (15-71)	87 ± 9.4 (49-100)	<.0001
JOA subscore			
Pain	6.8 ± 4.6 (0-20)	29.5 ± 1.5 (25-30)	<.0001
Function	10.1 ± 3.6 (3-19)	17.5 ± 3.3 (7-20)	<.0001
Range of motion	13.5 ± 5.3 (2-23)	21.9 ± 5.1 (7-30)	<.0001
Stability	4.1 ± 3.9 (–3 to 10)	9.4 ± 1.8 (0-10)	<.0001
Deformity	7.2 ± 2 (–1 to 10)	8.3 ± 1.7 (0-10)	<.0001

JOA, Japanese Orthopaedic Association.
Data are presented as mean ± standard deviation (minimum-maximum) in points.

Table III Evaluation of preoperative and postoperative range of motion, incidence of flexion contracture, and arc of supination and pronation

Evaluated item	Preoperative	Postoperative	*P* value
Flexion, °	109 ± 20 (45-150)	134 ± 11 (85-150)	<.0001
Extension, °	–38 ± 16 (–80 to 0)	–26 ± 15 (–75 to 0)	<.0001
Incidence of flexion contracture, % (n)	60 (45 of 75)	28 (21 of 75)	<.0001
Supination, °	60 ± 26 (0-90)	80 ± 18 (5-90)	<.0001
Pronation, °	59 ± 28 (0-90)	74 ± 19 (0-90)	<.0001
Arc of supination and pronation, °	119 ± 43 (0-180)	154 ± 31 (10-180)	<.0001

Data are presented as mean ± standard deviation (minimum-maximum) unless otherwise indicated.

Table IV Diameter of humeral stem and incidence of stress shielding

	No.	No. with stress shielding	Rate, %	Gruen system grade				
				No lucency	Incomplete		Complete	
					<2 mm	>2 mm	<2 mm	>2 mm
Stem diameter								
10 mm	23	8	35	0	4	4	0	0
9 mm	10	2	20	0	1	1	0	0
8 mm	42	1	2.4	0	1	0	0	0
Total	75	11	14	0	6	5	0	0

Table V Association between diameter of humeral stem and stress shielding

	Stress shielding		Total	*P* value
	Present	Absent		
9- and 10-mm-diameter stems	10	23	33	
8-mm-diameter stems	1	41	42	
Total	11	64	75	.0008

Table VI Complications after total elbow arthroplasty with MNSK system

	No. of cases	%
Periprosthetic infection	3	4
Fracture	4	5.3
Dislocation	2	2.7
Total	9	12

MNSK, Niigata-Senami-Kyocera modular.

Supination improved significantly from 60° ± 26° preoperatively to 80° ± 18° postoperatively, and pronation improved from 59° ± 28° to 74° ± 19°. The preoperative supination-pronation arc of 119° ± 43° increased significantly to 154° ± 31° postoperatively ($P < .0001$ for all) (Table III).

Radiographic assessment

Spot welds of the periphery of the humeral implant, which are the index of bone ingrowth, were achieved in all 75 elbows for which follow-up was possible. Stress shielding was evaluated in 74 cases; only 1 case was excluded because of deficiency of the postoperative radiographs. Stress shielding was seen in 11 elbows (14%); it was seen in 8 elbows (35%), 2 elbows (20%), and 1 elbow (2.4%) with upper arm diameters of 10 mm, 9 mm, and 8 mm, respectively (Table IV). According to the Gruen system, all cases were of the incomplete type. Among these, a radiolucent sign greater than 2 mm was observed in 5 elbows (Table IV). These findings showed that compared with the 8-mm-diameter group, stress shielding was significantly higher in the 9- and 10-mm-diameter groups ($P = .0008$, χ^2 test) (Table V).

Follow-up of stress shielding by radiography could be performed for 10 of 11 elbows. The mean duration of follow-up was 2.6 years (range, 0.08-5.42 years). In 5 elbows, the condition was progressive, and the mean duration from the primary surgical procedure to the appearance of stress shielding was 1.3 years (range, 0.08-4.79 years). With the exception of 1 elbow with a titanium alloy component that was excluded because the ulnar component was removed owing to infection, the radiographic examination of ulnar components showed no loosening in 74 elbows.

Complications

Complications were detected in 9 patients (9 elbows, 12%) (Table VI), detailed as follows: periprosthetic joint infection in 3 elbows (4.0%), fracture in 4 (5.4%) (intraoperative medial condyle fracture in 2, intraoperative lateral condyle fracture in 1, and postoperative ulnar fracture in 1), and dislocation after artificial elbow arthroplasty in 2 (2.6%). All the cases of periprosthetic infection were late-onset cases (Table VII). The durations from the primary surgical procedure to the onset of infection were 1.4, 0.5, and 1.5 years. Two patients (cases 1 and 2) were treated with methotrexate (6 mg/week and 8 mg/week, respectively), and the other patient (case 3) was treated with intravenous tocilizumab (8 mg/kg for 4 weeks). None of these patients was treated with steroids. Pathogenic bacteria were methicillin-sensitive *Staphylococcus aureus* in 2 patients (cases 1 and 3) and *Citibacterium acnes* (case 2). Revision surgery was performed in cases 1 and 3, and the MNSK system was salvaged by continuous irrigation therapy with débridement in case 2 (Table VII). Regarding case 2, implant fixation was good after débridement, so irrigation therapy was continued for 18 days (160 mL/h with normal saline solution), and the wound finally healed.

Intraoperative humeral condyle fractures were treated with concomitant osteosynthesis (Fig. 4); the causes of fractures were malpositioning when the humeral stem was inserted or strong impaction when the humeral condyle component was inserted. A postoperative ulnar fracture was treated conservatively, and bone union was achieved. Regarding the 2 cases of dislocation, reconstruction was performed for 1 patient using the Leeds-Keio ligament (Yufu, Tokyo, Japan).[19]

Table VII Details of 3 cases of periprosthetic infection

Case No.	Age, yr	Sex	Side	RA duration at primary TEA, yr	Duration between surgery and onset of periprosthetic infection, yr	MTX, mg/week	bDMARD	PSL, mg/d	Pathogenic bacteria
1	41	F	R	3	1.4	6	NA	0	MSSA
2	59	M	R	7	0.5	8	NA	0	*C acnes*
3	61	F	R	30	1.5	NA	TCZ	0	MSSA

RA, rheumatoid arthritis; *TEA*, total elbow arthroplasty; *MTX*, methotrexate; *bDMARD*, biological disease-modifying antirheumatic drug; *PSL*, methylprednisolone; *F*, female; *R*, right; *MSSA*, methicillin-sensitive *Staphylococcus aureus*; *M*, male; *NA*, not applicable; *TCZ*, tocilizumab.

Problems with wound healing occurred in 1 patient, and additional neurolysis and subcutaneous anterior advancement of the ulnar nerve were required in 1 patient in whom postoperative ulnar neuropathy developed. No patients had triceps tendon avulsions as complications, but persistent instability was detected in the 2 cases of dislocation.

Survival rates

The survival rates were 97% at 5 years and 93% at 10 years after the primary surgical procedure according to the Kaplan-Meier curve (Fig. 5).

Discussion

The indication for artificial elbow arthroplasty with the MNSK system is elbow joint destruction, including instability with elbow joint deformity up to Larsen grade IV. In cases of Larsen grade V deformity, the ulnar component of the MNSK system is very difficult to position because the thickness of the olecranon head is frequently too thin. Therefore, we have indicated the constrained type of artificial elbow joint in cases of Larsen grade V deformity. However, actually in our study, 3 patients with Larsen V deformity were included. All patients required an iliac bone graft because the olecranon was too thin for the ulnar component to be positioned without bone graft.

Regarding the outcome of unconstrained-type artificial elbow arthroplasty in RA, Tanaka et al[27] reported good outcomes and survivorship (90% at 16 years) of elbow arthroplasty with the Kudo type 3 prosthesis in 47 patients (50 elbows). Plaschke et al[22] compared the Kudo type 3 prosthesis with the constrained type and reported a favorable comparison. Kato et al[15] described 33 elbows that received a Kudo type 5 prosthesis with a mean follow-up period of 7 years. They mentioned that the JOA score increased significantly from 49.8 points to 81.5 points, and excluding extension, the range of motion of the joint increased significantly for flexion, pronation, and supination. In our study, the JOA score and range of motion of the elbow joint also improved significantly compared with before surgery. The 5-year postoperative long-term follow-up showed a good functional prognosis, which is in agreement with these previous reports.

Kodama et al[16] assessed the long-term outcomes of the Kudo type 5 prosthesis in 31 patients (41 elbows) with RA. The survivorship rates were 87.8% after 5 years and 70.7% after 10 years, and the Mayo Elbow Performance Score increased from 43 preoperatively to 80 at the final follow-up. Survivorship in our study (97% at 5 years and 93% at 10 years) was superior to that with the Kudo type 5 prosthesis. We speculate that the causes of the good outcomes in our study are as follows: (1) The surgical approach with the Tsuge technique[28] is not invasive compared with the Campbell approach, which dissociates the continuity of the triceps tendon. (2) The lateral collateral ligament is tightly repaired to prevent postoperative subluxation and dislocation, and the ulnar collateral ligament is preserved. (3) Because of the implant design of the MNSK system, osteotomy is relatively minimal or limited.

In our department, we started using the NSK unconstrained type of artificial elbow joint in 1988. This device was designed based on the concept in which the center of the humeral system is attached to one-third of the posterior part of the pulley, and the rotating center moves forward. Then, the thick, 10-mm-diameter stem is inserted into the medullary cavity as much as possible. Accurate osteotomy enables support of a wide load in the distal humerus. At that time, the humeral stem was a single-crystal alumina stem.[11] We reported the results of using the NSK artificial elbow joint in 2008. We examined 47 patients (49 elbows) with a mean age of 63 years and mean postoperative follow-up time of 10 years. The JOA functional evaluation score of the elbow joint increased from 37 to 81 points postoperatively. In the humeral stem, a cementless implant was used for 21 elbows, which was approximately half of them. However, loosening of the humeral implant was seen in all patients. Hence, the rigidity of the humeral cementless implant became increasingly important.[1] To solve these problems, the MNSK type of artificial elbow joint was developed and has been in use since 1998. In contrast to the single-crystal alumina stem, the humeral stem was made of titanium alloy. To promote bone ingrowth in the system, a rough surface film was made by the inert gas–shielded metal arc thermal spray method. Moreover, it became possible to select not only a stem diameter

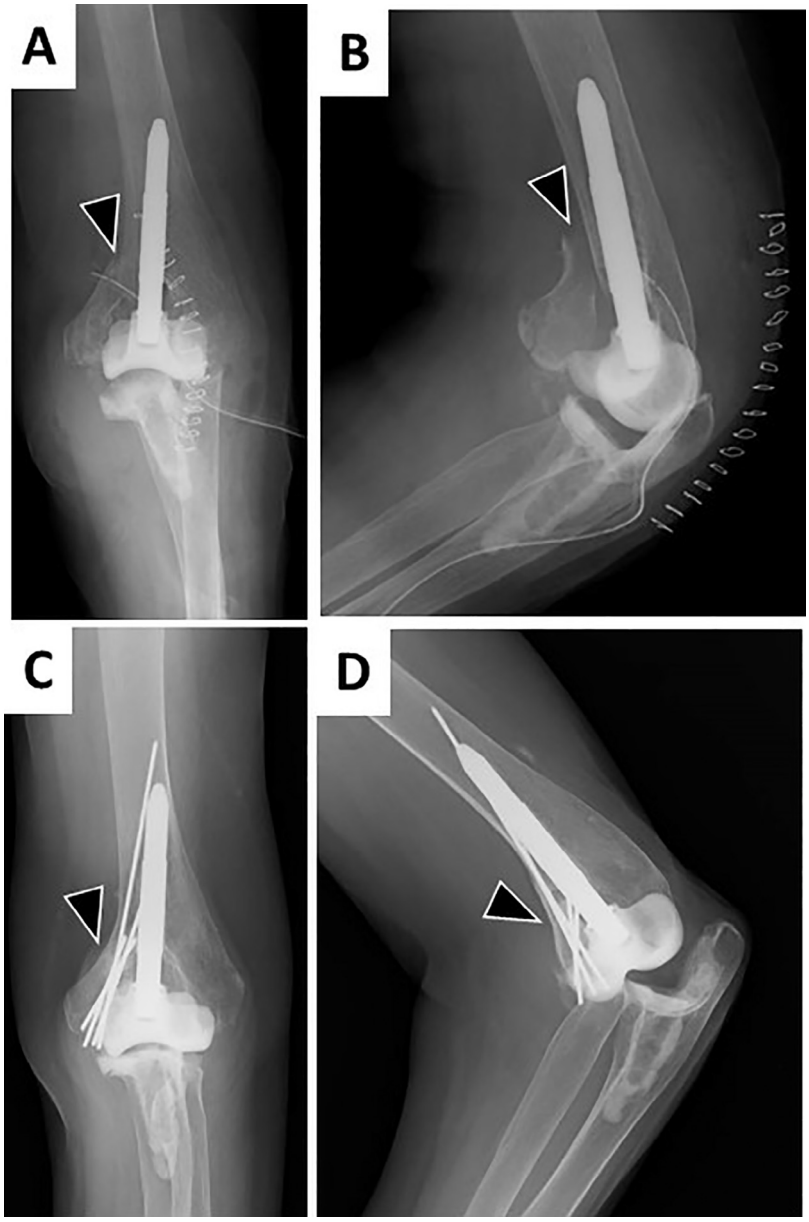

Figure 4 Representative case of intraoperative fracture. **(A, B)** In a 76-year-old woman with rheumatoid arthritis, the direction of the humeral stem is deviated radially, and a humeral medial condyle fracture (*arrowheads*) is detected on the radiographs of the left elbow just after the primary surgical procedure. On the same day, reoperation was performed. The humeral stem, which had been fixed with bone cement, and the humeral condyle component were removed. The fracture site was exposed, reduced, and fixed with 4 Kirschner wires. Then, the humeral stem and condyle were inserted again. **(C, D)** Fracture healing was achieved 1 year after internal fixation (*arrowheads*), but malrotation of the humeral component and anterior subluxation remained. The patient's Japanese Orthopaedic Association elbow function score increased from 54 points preoperatively to 74 points at the final follow-up.

of 10 mm but also stem diameters of 9 and 8 mm. Herein, the condyle was ceramic and cement was used to fix it.

When we previously used the NSK system, we used a stem 10 mm in diameter to acquire bone ingrowth in almost all cases. However, our previous report about the MNSK system showed that stress shielding surrounding the humeral condyle component was detected in 5 of 13 elbows (38%), in which 10-mm-diameter stems were inserted and more than 5 years of follow-up was possible.[1] However, stress shielding was never detected in 8 of 8 elbows in which an 8-mm-diameter stem was implanted. Thereafter, we have used an 8-mm-diameter stem for the humeral component.

As shown by the findings of stress shielding of the humeral component, strong bone ingrowth can be obtained in the spray area; however, torsion (twisting), flexion, and extension of the elbow joint impart stress on that partial stem area.

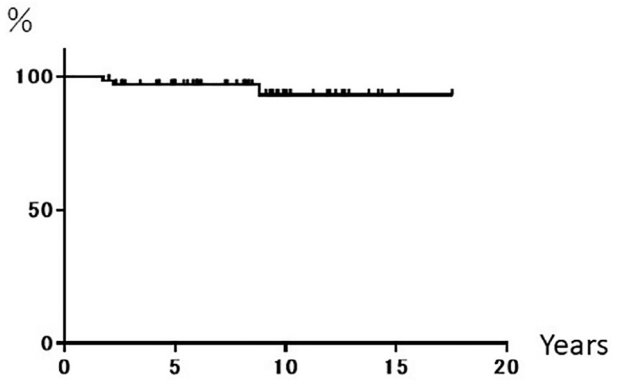

Figure 5 Kaplan-Meier curve. The 5-year survival rate is 97%, and the 10-year survival rate is 93%.

Relatively, the condyle area is barely affected by stress. Therefore, the surroundings of the condyle component are absorbed gradually, particularly from the medial part, and when the extent increases, the surroundings up to the lateral part become absorbed. Our data showing that the 8-mm-diameter stem was statistically associated with a lower frequency of stress shielding prove that the risk of stress shielding increases with the 9- and 10-mm-diameter stems, suggesting that their use must be avoided. However, a limitation of our study is that our data were not prospectively collected.

Furthermore, among the 10 patients with the onset of stress shielding, the condition was progressive in 5 at less than 2 years after the primary surgical procedure. We therefore assumed that the progressive state will be the cause of further fracture and dullness of the implant surroundings. Use of the 8-mm-diameter stem was shown to notably decrease the rate of stress shielding.

Stress shielding is observed with well-fixed implants in which bone resorption occurs in regions where load transfer across the implants bypasses a portion of the bone.[5] For instance, Engh and Bobyn[6] examined the relationship between the diameter of porous-coated cementless stems and the incidence of stress shielding in hip replacement. The use of larger stems resulted in an increased occurrence of marked bone resorption: Stems greater than or equal to 13.5 mm in diameter showed 5 times the incidence of pronounced resorption as stems less than or equal to 12.0 mm in diameter.[6] Regarding humeral porous-coated cementless stems in the MNSK system, those measuring 10 or 9 mm in diameter can cause stress shielding around the humeral condyle component. We assume that the smaller stem does not cause a lack of component fixation because an 8-mm-diameter humeral stem never caused symptomatic loosening. We think that stress shielding is not associated with component loosening of the humeral stem because bone ingrowth was acquired around the cementless humeral stem component, and this is why no patient had complete-type stress shielding according to the Gruen system (Table IV).

Regarding the ulnar component, Brinkman et al[4] reported postoperative loosening in 7 of 49 elbows with the Kudo type 5 prosthesis due to malpositioning after cementless fixation. In addition, Kodama et al[16] reported that aseptic loosening of the ulnar component occurred after TEA in 11 of 42 elbows with the Kudo type 5 prosthesis. In our study, cement fixation of the ulnar component was performed in all patients, excluding those with infection; no loosening occurred, and the outcome was good.

Various rates of infection after artificial elbow arthroplasty have been reported, ranging from 1.9% to 13.3%.[8,10,14,30] Even in our study, periprosthetic infection occurred in 3 elbows (4.0%); thus, this complication requires careful attention.

In addition, even when revision surgery is required, the cementless humeral stem can be removed by temporarily splitting the humeral posterior cortex longitudinally. Then, the part with bone ingrowth can be released using a step-by-step process and a thin chisel. Moreover, as the condylar bone remains intact, revision surgery can be performed using the same equipment.[12] If the uncemented implant is unstable, the humeral stems need to be removed and replaced with some type of convertible piece. Actually, the MNSK system has a cemented humeral stem that is longer than the conventional cementless humeral stem.

The limitations of this study are as follows: (1) The patient-reported functional outcome of the elbow was not evaluated; (2) the follow-up duration was short; and (3) the precise mechanism associated with the incidence of stress shielding remains unknown.

Conclusion

The functional assessment of artificial elbow arthroplasty with the MNSK system was good. Regarding the humeral stem, stress shielding occurs at a higher rate with the 10- and 9-mm-diameter stems. The ulnar component was set in place by cement fixation in all patients, aside from the cases of infection in which its removal was necessary, and there was no loosening. There were 3 cases (4.0%) of periprosthetic infection; therefore, this complication requires careful attention.

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