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Author(s)	Onodera, Jun; Kondo, Eiji; Omizu, Nobuyuki; Ueda, Daisuke; Yagi, Tomonori; Yasuda, Kazunori
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Beta tricalcium phosphate shows superior absorption rate and osteoconductivity compared to hydroxyapatite in open wedge high tibial osteotomy

Running title: Comparisons of Synthetic Spacers in High Tibial Osteotomy

<sup>1</sup>Jun Onodera, MD, PhD; <sup>1</sup>Eiji Kondo, MD, PhD; <sup>2</sup>Nobuyuki Omizu, MD, PhD;

<sup>2</sup>Daisuke Ueda, MD; <sup>2</sup>Tomonori Yagi, MD, PhD; <sup>1</sup>Kazunori Yasuda, MD, PhD

From <sup>1</sup>the Department of Sports Medicine and Joint Surgery, Hokkaido University Graduate School of Medicine, Sapporo, Hokkaido, Japan, and <sup>2</sup>the Department of Orthopaedic Surgery, Yamanote-dori Yagi Hospital, Sapporo, Hokkaido, Japan

\*Address correspondence to: Eiji Kondo, MD, PhD, Associate Professor, Department of Sports Medicine and Joint Surgery, Hokkaido University Graduate School of Medicine, Kita-15 Nishi-7, Kita-ku, Sapporo, 060-8638, Japan.

Tel: +81-11-706-7211, Fax: +81-11-706-7822, E-mail: [eijik@med.hokudai.ac.jp](mailto:eijik@med.hokudai.ac.jp)

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1 **Abstract**

2 **Purpose:** The purpose of this study was to clinically and radiologically compare the  
3 utility, osteoconductivity, and absorbability of hydroxyapatite (HAp) and  
4 beta-tricalcium phosphate (TCP) spacers in medial open wedge high tibial osteotomy  
5 (HTO).

6 **Methods:** Thirty-eight patients underwent medial open wedge HTO with a locking  
7 plate. In the first 19 knees, a HAp spacer was implanted in the opening space (HAp  
8 group). In the remaining 19 knees, a TCP spacer was implanted in the same manner  
9 (TCP group). All patients underwent clinical and radiological examinations before  
10 surgery and at 18 months after surgery.

11 **Results:** Concerning the background factors, there were no statistical differences  
12 between the two groups. Postoperatively, the knee score significantly improved in each  
13 group. Concerning the postoperative knee alignment and clinical outcome, there was no  
14 statistical difference in each parameter between the two groups. Regarding the  
15 osteoconductivity, the modified van Hemert's score of the TCP group was significantly  
16 higher ( $p=0.0009$ ) than that of the HAp group in the most medial osteotomy zone. The  
17 absorption rate was significantly greater in the TCP group than in the HAp group  
18 ( $p=0.00039$ ).

19 **Conclusions:** The present study demonstrated that a TCP spacer was significantly  
20 superior to a HAp spacer concerning osteoconductivity and absorbability at 18 months  
21 after medial open wedge HTO.

22 **Level of Evidence:** III, Retrospective comparative study

23 **Keywords:** Open wedge high tibial osteotomy; Beta-tricalcium phosphate;  
24 Hydroxyapatite; Wedge-shaped spacer; Knee osteoarthritis

25 **Introduction**

26 High tibial osteotomy (HTO) has been a useful surgical option for medial osteoarthritis  
27 (OA) of the knee. Recently, the medial open wedge HTO with a locking plate has  
28 attracted a great deal of attention [3,7,14,20,26,28,34,35]. However, the open wedge  
29 HTO has the disadvantage that a large vacant space is left in the proximal tibia after  
30 surgery [2,16,33]. In addition, it is known that it takes a long period, a few months or  
31 more, until the open space created in the tibia after alignment correction is filled with  
32 regenerated bone [21,36]. Recently, therefore, a wedge-shaped spacer made from  
33 hydroxyapatite (HAp) or beta-tricalcium phosphate (TCP) has been used to fill the  
34 vacant space in the open wedge HTO [21,32,34,36]. However, it is necessary for a  
35 spacer for the open wedge HTO to have not only sufficient strength but also high  
36 osteoconductivity and absorbability. The former ability is one of the minimum  
37 requirements of a synthetic bone [22]. The latter ability is necessary to avoid a possible  
38 risk that the strong spacer implanted in the tibia may cause an obstacle in revision  
39 surgery after HTO [32]. Therefore, it can be useful to assess the osteoconductivity and  
40 absorbability of ceramic spacers after medial open wedge HTO. A number of previous  
41 basic studies reported that HAp and TCP ceramics have excellent osteoconductivity  
42 under various experimental conditions, while they have different absorbability

43 [6,9,12,15,19,23,24,27,43,45]. However, the experimental conditions used in these basic  
44 studies are different from the biological and biomechanical environments surrounding  
45 synthetic spacers implanted into the tibia of patients. Therefore, commonly, the  
46 osteoconductivity and absorbability of the HAp or TCP spacers must be evaluated in  
47 each clinical lesion where the spacer is implanted. However, no clinical study so far has  
48 compared the osteoconductivity and absorbability of the HAp or TCP spacers in the  
49 tibia with medial open wedge HTO. Based on previous studies, it has been hypothesized  
50 that the osteoconductivity and absorbability of the TCP spacer might be higher in  
51 comparison to the HAp spacer. The purpose of this study is to test this hypothesis.

52

### 53 **Materials and Methods**

54 A retrospective comparative study was performed with 45 patients who underwent  
55 medial open wedge HTO with a locking compression plate (Tomofix, Synthes, Bettlach,  
56 Switzerland). Inclusion criteria used in this study involved patients who had persistent  
57 pain due to medial compartment OA or spontaneous osteonecrosis of the medial  
58 femoral condyle, after they received conservative treatment for 3 months or more.  
59 Exclusion criteria in this study included (1) patients whose lateral femorotibial angle  
60 (FTA) was more than  $185^{\circ}$ ; (2) patients who had an extension loss of more than  $15^{\circ}$ ; (3)

61 patients who had a range of knee motion less than 130°; (4) patients who had a history  
62 of infection in the knee; (5) patients who had severe OA in the patellofemoral joint, (6)  
63 patients who had anterior cruciate ligament insufficiency or varus/valgus instability of  
64 more than 10°.

65           Between 2009 and 2010, 23 patients were enrolled in this study. In these  
66 patients, we used a HAp spacer (NEOBONE, Covalent Materials, Tokyo, Japan) in  
67 HTO. Between 2010 and 2011, 22 patients were enrolled. In these patients, a TCP  
68 spacer (OSferion, Olympus-Terumo Biomaterials, Tokyo, Japan) was used in HTO. The  
69 biomaterial characteristics of the HAp and TCP ceramics used are shown in Table 1. In  
70 each patient, computed digital radiographs (Fujifilm, Miyagi, Japan) were taken to  
71 evaluate alignment changes before and immediately after surgery. Clinical and  
72 radiological follow-up examinations were performed at 18 months after surgery. The  
73 evaluations of the spacer were not obstructed by the implanted plate, because it had  
74 been removed at approximately 1 year after HTO. However, in the first group, 4  
75 patients did not have the plate removed so only the remaining 19 patients (83%) could  
76 be evaluated as the HAp group. In the second group, 3 patients did not have the plate  
77 removed, leaving the remaining 19 patients (86%) as the TCP group. The follow-up  
78 period averaged 18 (8) months in the HAp group, and 17 (7) months in the TCP group.



79

## 80 **Patient Demographics**

81 In the HAp group, there were 14 women and 5 men with a mean age of 61.0 years at the  
82 time of surgery. Concerning the radiological OA grade, this group included 8 knees of  
83 grade 2 and 11 knees of grade 3 [18]. We found spontaneous osteonecrosis in 1 knee. In  
84 the TCP group, there were 17 women and 2 men with a mean age of 60.5 years.  
85 Regarding the OA grade, this group included 8 knees of grade 2, 10 knees of grade 3,  
86 and 1 knee of grade 4. We found spontaneous osteonecrosis in 1 knee. The background  
87 factors of the 2 groups are shown in Table 2, including body mass index (BMI), and %  
88 young adult mean (YAM) of bone mineral density (BMD). There were no statistical  
89 differences in the background factors between the 2 groups. The clinical and  
90 radiological status of the 2 groups is shown in Table 3, including range of knee motion,  
91 knee evaluation score (Japan Orthopaedic Association: JOA score), the OA grade, FTA,  
92 weight-bearing line (WBL), the tibial slope, and the Insall-Salvati ratio [4,44]. There  
93 were no statistical differences between the 2 groups.

94

## 95 **Procedure of Medial Open Wedge HTO**

96 The proximal tibia was exposed through a 7-cm medial longitudinal incision. Then, we

97 performed a biplanar osteotomy of the tibia, which consisted of an oblique HTO and a  
98 frontal plane osteotomy behind the tibial tubercle [36], using a micro bone saw. Then,  
99 the oblique osteotomy site was gradually opened by use of a specially designed spreader  
100 under fluoroscopic control so that the valgus angulation of the knee became 10°.

101 From a rectangular block of HAp or TCP, we intra-operatively created a  
102 wedge-shaped spacer using a custom-made circular saw system (Fig. 1A). During each  
103 surgery, we created 2 wedge-shaped spacers, and they were implanted parallel into the  
104 anterior part and posterior part of the opening (Fig. 1B). Then, we fixed the tibia with a  
105 locking compression plate (Tomofix, Synthes) by inserting 8 locking screws (Fig. 1C).

106

### 107 **Postoperative Rehabilitation**

108 Straight leg raising and quadriceps setting exercises as well as active and passive knee  
109 motion exercises were encouraged from the next day after surgery. Partial  
110 weight-bearing on the tibia was permitted with crutches at 2 weeks after surgery. Full  
111 weight-bearing was allowed at 4 weeks after surgery.

112

### 113 **Clinical and Radiological Evaluations**

114 The patients were evaluated using the JOA Score [4,44]. The clinical evaluations were

115 carried out twice, before surgery and at the final follow-up period. The radiological  
116 stage of osteoarthritis was assessed according to the Kellgren-Lawrence grading system  
117 [18] based on an anteroposterior radiograph of the knee.

118 The FTA was measured on an anteroposterior weight-bearing radiograph of a  
119 single leg, with the knee joint in extension. The WBL percentages and the entire leg  
120 length were measured on an anteroposterior radiograph of the whole lower limb taken  
121 with a long cassette in the one-leg standing position. The FTA was defined as the angle  
122 between the axis of the femoral shaft and the axis of the tibial shaft on the fibular side.

123 To calculate the WBL, a line was drawn from the center of the femoral head to the  
124 middle point of the proximal talar joint surface. The WBL percentage was defined as  
125 the horizontal distance from the WBL to the medial edge of the tibial plateau, divided  
126 by the width of the tibial plateau. The entire leg length was defined as the distance

127 between the top of the femoral head and the center of the tibial plafond. The

128 Insall-Salvati index [25] and tibial slope [29] were estimated on lateral radiographs. The

129 Insall-Salvati ratio, defined as the length of the patellar tendon (from the inferior pole of

130 the patella to the tibial tubercle) divided by the patellar height (longest coronal

131 dimension of the patella), was calculated. The tibial slope was measured as the angle

132 between the line perpendicular to the mid-diaphysis of the tibia and the posterior

133 inclination of the tibial plateau on the lateral view. Test–retest reliability was assessed  
134 by calculation of Pearson correlation coefficient. A test–retest reliability experiment for  
135 each measurement confirmed a high reliability between time point one and two with  
136  $P < 0.01$  and  $r = 0.90$  demonstrating a strong correlation.

137         To assess the osteoconductivity on an anteroposterior radiograph, we drew a  
138 triangle that showed the wedge-shaped space created by open wedge HTO, and divided  
139 this triangle into 4 zones (Fig. 2) [8]. The most medial zone was named “Zone I”. Then,  
140 we named the next 3 zones “Zones II, III, and IV (the most lateral zone)”, respectively.  
141 In each zone, we graded new bone formation in a thin space between the bone surface  
142 created by osteotomy opening and the inserted spacer surface, using the modified van  
143 Hemert’s rating system [39] (Fig. 3): Namely, 0 point was given when an osteotomy  
144 line on the tibia was as clear as that immediately after surgery and we could not find any  
145 new bone formation on neither the proximal nor distal surface of the spacer: One point  
146 was given when an osteotomy line on the tibia became unclear but a distinct lucent line  
147 was clearly visible on both the proximal and distal surface of the spacer: Two points  
148 were given when a blurred lucent line was visible in a limited part on both the proximal  
149 and distal surface of the spacer: Three points were given when a blurred lucent line was  
150 clearly visible on one surface of the spacer but not visible at all on the other surface:

151 Four points were given when a blurred lucent line was visible in a limited part on one  
152 surface of the spacer but not visible at all on the other surface: Five points were given  
153 when no lucent line was visible at all on either surface of the spacer.

154 To assess the absorbability of each spacer, the area of the implanted spacer on  
155 the anteroposterior radiograph was measured with the NIH Image J (National Institutes  
156 of Health, Bethesda, Maryland) immediately after surgery (A0) and at the final  
157 follow-up period (A1). We defined a rate given by the formula,  $(A0-A1)/A0$ , as the  
158 “absorption rate” of each implanted spacer. First, a digital image file of a radiograph  
159 was opened by the NIH image J. Then, for setting measurement scale, the maximum  
160 joint width of the proximal tibia was marked on the anteroposterior radiograph as a  
161 baseline. The automated threshold included only the spacer area. Finally, the area of the  
162 spacer was calculated.

163 Prior approval was given from the Investigational Review Board, the Ethics  
164 Committee of Hokkaido University (Reference number: 012-0360).

165

## 166 **Statistical Analysis**

167 All data were shown as means with standard deviations. For each parameter, unpaired  
168 Student’s  $t$  test and  $\chi^2$  test were performed between the two groups. The Pearson

169 correlation coefficient was used to characterize the size of the wedge and the  
170 osteoconductivity. A commercially available software program (StatView, SAS Institute,  
171 Cary, North Carolina) was used for statistical calculation. The significance level was set  
172 at  $p=0.05$ . Concerning the absorption rate, reproducibility was high as represented by  
173 both the intra-observer (mean ICC = 0.93; range 0.89–0.97) and the inter-observer  
174 (mean ICC = 0.87; range 0.8–0.93) reliability measurements.

175

## 176 **Results**

### 177 **Comparison of postoperative alignment after HTO**

178 The size of the wedge spacer averaged 13.2 (1.9) mm and 12.1 (2.3) mm in the HAp  
179 and TCP groups, respectively (Fig. 4). There was no significant difference in the size of  
180 each spacer. Immediately after surgery (Table 4), concerning the mean opening angle,  
181 the opening distance, the FTA, the tibial slope, and Insall-Salvati ratio, there was no  
182 significant difference in each parameter between the 2 groups.

183         At the final follow-up examination (Table 5), the FTA averaged  $169.8^\circ$  in both  
184 groups. The FTA, the tibial slope, and the Insall-Salvati ratio did not significantly  
185 change between the 2 examination periods in each group. In addition, again, there was  
186 no significant difference in each parameter between the 2 groups.

187

188 **Comparison of osteoconductivity and absorbability of the HAp or TCP spacers**

189 Concerning the osteoconductivity, the modified van Hemert's score in the TCP group  
190 (4.5 (0.8) points) was significantly higher ( $p=0.0009$ ) than that of the HAp group (3.2  
191 (1.3) points) in zone 1(Fig. 5), while there were no significant differences between the 2  
192 groups in the other zones. The absorption rate averaged 0.9 (19.6) % in the HAp group  
193 and 25.3 (18.5) % in the TCP group. The absorption rate was significantly greater in the  
194 TCP group than in the HAp group ( $p=0.00039$ ). There was no significant relationship  
195 between the size of the wedge and the osteoconductivity in the HAp and TCP groups.

196

197 **Comparison of postoperative clinical results of HTO**

198 All the patients underwent the second surgery for removal of the fixation plate at a  
199 mean period of 12 (1.6) and 13 (3.7) months in the HAp and TCP groups, respectively.  
200 There were no intra- and post-operative complications in either group. In the final  
201 clinical examination (Table 5), the medial pain in the knee joints had resolved in all  
202 cases. Postoperatively, the mean JOA score significantly improved at the final  
203 follow-up in the both groups. There were no significant differences between the 2  
204 groups.

205

206 **Discussion**

207 The most important finding of the present study was that the osteoconductivity in the  
208 TCP group was significantly higher than in the HAp group in the most medial  
209 osteotomy zone. The absorption rate was also significantly greater in the TCP group  
210 than in the HAp group. Postoperatively, the knee score improved significantly in each  
211 group. Regarding the knee alignment, there was no statistical difference in each  
212 parameter between the HAp and TCP groups.

213 It was considered why the osteoconductivity was superior in the TCP group  
214 compared with the HAp group. According to the manufacturer's information, the HAp  
215 ceramics have 75% porosity and interconnected macropores. However, this HAp does  
216 not have micropores in the walls of its macropores. On the other hand, the TCP  
217 ceramics used in this study have 60% porosity, and macro and microstructures, with  
218 interpore connections. Previously, several researchers have reported an important role of  
219 the microstructure in the behavior of bone cells and bone metabolism [12,31,40]. Lu et  
220 al [27] reported on implanted cylinders of HAp and TCP ceramics in the cortical,  
221 cancellous, and medullar bone sites using rabbits. The bone/implant interface contact  
222 was better in TCP than in HAp, especially in the cortical site. In this study, the



223 osteoconductivity of the TCP group was significantly higher than that of the HAp group  
224 in the most medial osteotomy zone. This zone corresponds to the ‘cortical bone’ site.  
225 From these results, it is considered that the micropores of the TCP provided a better  
226 substrate or microenvironment for osteoblastic cell formation [40,41].

227 TCP is thought to be largely degraded by hydrolysis in vitro and is absorbed  
228 more rapidly than HAp in vivo [11,13,41]. There may be many other factors that  
229 influence the in vivo degradation of materials [6,10,12,22,40], and the role of such  
230 factors has not yet been clarified. It has been suggested that the mechanism of  
231 bioceramic resorption involves two processes, which are solution-mediated and  
232 cell-mediated disintegration [10,15]. Solution-mediated disintegration is associated with  
233 the composition of the material itself as well as the surrounding environment [17].  
234 Cell-mediated disintegration is mainly caused by osteoclasts [42]. Histological  
235 assessment [43] revealed that numerous osteoclasts were present on the surface of the  
236 TCP. In the HAp, however, few osteoclasts were detected. This may cause the  
237 above-described differences in the clinical lesion after medial open wedge HTO.

238 Previous basic studies investigated the absorbability of TCP ceramics with  
239 several porosities [11]. Lu et al [27] reported on implanted cylinders of TCP with 52%  
240 porosity in the rabbit femur. The material degradation rate of the TCP was 29%, 55%,

241 and 75% in the cortical, cancellous, and medullar bone, respectively, at 24 weeks after  
242 implantation. In human studies, Ogose et al [30] reported on implantation of TCP with  
243 75% porosity after excision of bone tumor. They reported that all cases displayed almost  
244 total resorption of TCP on radiograph at 26 months after surgery. However, Altermatt et  
245 al [1] reported that most implanted TCP with 60% porosity remains at least 7 years in  
246 calcaneal bone defects. Regarding implantation in the HTO, Tanaka et al [37] reported  
247 implantation in patients of TCP blocks with 75% and 60% porosities in medial open  
248 wedge HTO. In their report, nearly complete resorption of TCP was obtained within 3.5  
249 years. However, in this study, it was noted that the absorption rate of the TCP spacer  
250 averaged only 25% at 18 months after surgery. Therefore, the absorbability of the TCP  
251 may depend on its porosity, volume, and shape, as well as the implant location.

252         Medial open wedge HTO can be performed without any spacer [26,35].  
253 However, correction loss and screw breakage after open wedge HTO have been reported  
254 [38]. It is widely agreed that autografting is the gold standard and allografting is a  
255 secondary option [11,13,16]. However, autografts have some problems, including donor  
256 site morbidity, while allografts have disadvantages such as the potential to provoke an  
257 immune response and the risk of disease transmission [5]. The main disadvantage of  
258 HTO is the long period of rehabilitation needed after surgery [26,35]. However,

259 Takeuchi et al [36] reported that an early weight-bearing exercise program enables full  
260 weight bearing at 2 weeks after medial open wedge HTO with Tomofix plate (Synthes)  
261 and TCP wedges. Therefore, based on these advantages, we expect a spacer to enhance  
262 bony healing after medial open wedge HTO. However, an implanted spacer may  
263 become a serious problem in various revision surgeries in the future. Therefore, we  
264 believe that an ideal spacer for medial open wedge HTO must have high clinical utility,  
265 high osteoconductivity, and high absorbability. The present study showed that there  
266 were no significant differences concerning the clinical utility between the HAp and TCP  
267 spacers in medial open wedge HTO. From the viewpoint of clinical utility, this study  
268 suggested that these spacers, with excellent biocompatibility, are equally useful for  
269 medial open wedge HTO with a locking plate.

270           There are some limitations in this study. First, the follow-up period averaged  
271 only 18 months. Therefore, at the present time, we cannot speculate whether there will  
272 be differences between the HAp and TCP ceramics in long-term outcome of knee  
273 function, and absorbability. Second, only anteroposterior radiographs were used for  
274 bone union evaluation. Third, we had no histological evaluation of the bone union site.  
275 However, these preliminary short-term follow up human data will be a turning point for  
276 the issue of bone union for medial open wedge HTO. These results suggest that the TCP

277 spacer is superior to the HAp spacer concerning osteoconductivity and absorbability.  
278 However, middle- and long-term follow-up evaluations are needed to confirm the  
279 superiority found in the present study.

280

## 281 **Conclusion**

282 The present study showed that there were no significant differences concerning the  
283 clinical utility between the HAp and TCP spacers in open wedge HTO at 18 months  
284 after surgery. The osteoconductivity of the TCP spacer was slightly but significantly  
285 higher than that of the HAp spacer after HTO, and the absorbability of the TCP spacer  
286 was also significantly greater than that of the HAp spacer after HTO.

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409 **Figure Legends**

410 Fig. 1

411 Two HAp or two TCP wedges were formed in a triangle pole (a) equivalent to the size  
412 of the opening and then inserted into the osteotomy site to fit into the medial cortical  
413 bone edge (b). (c) After implantation of the ceramic spacer, a low profile locking plate  
414 (TomoFix, Synthes) was fixed in place with 8 locking screws.

415

416 Fig. 2

417 A triangle on digitized anteroposterior radiographs, with the sides of the triangle being  
418 along the borders and corner of the osteotomy. This triangular surface was then divided  
419 into four zones of the same surface area on the radiographs. These zones were  
420 numbered 1 to 4, starting from the medial cortex.

421

422 Fig. 3

423 The modified van Hemert's rating system: Namely, 0 point was given when an  
424 osteotomy line on the tibia was as clear as that immediately after surgery and we could  
425 not find any new bone formation on neither the proximal nor distal surface of the  
426 spacer: One point was given when an osteotomy line on the tibia became unclear but a

427 distinct lucent line was clearly visible on both the proximal and distal surface of the  
428 spacer: Two points were given when a blurred lucent line was visible in a limited part  
429 on both the proximal and distal surface of the spacer: Three points were given when a  
430 blurred lucent line was clearly visible on one surface of the spacer but not visible at all  
431 on the other surface: Four points were given when a blurred lucent line was visible in a  
432 limited part on one surface of the spacer but not visible at all on the other surface: Five  
433 points were given when no lucent line was visible at all on either surface of the spacer.

434

435 Fig. 4

436 Diagrams of the size of each spacer for the HAp and TCP groups. The size of the wedge  
437 spacer averaged 13.2 (1.9) mm and 12.1 (2.3) mm in the HAp and TCP groups,  
438 respectively (Fig. 4). There was no significant difference in the size of each spacer.

439

440 Fig. 5

441 Concerning osteoconductivity, the modified van Hemert's score of the TCP group was  
442 significantly higher ( $p=0.015$ ) than that of the HAp group in the most medial osteotomy  
443 zone, while there were no significant differences between the 2 groups in the other  
444 zones.

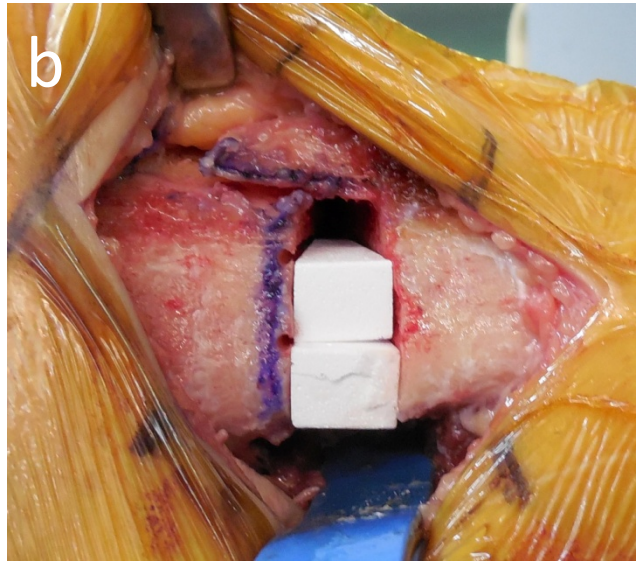
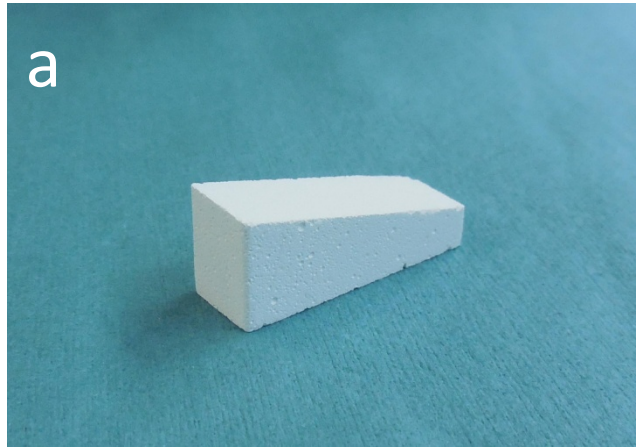


Figure 1

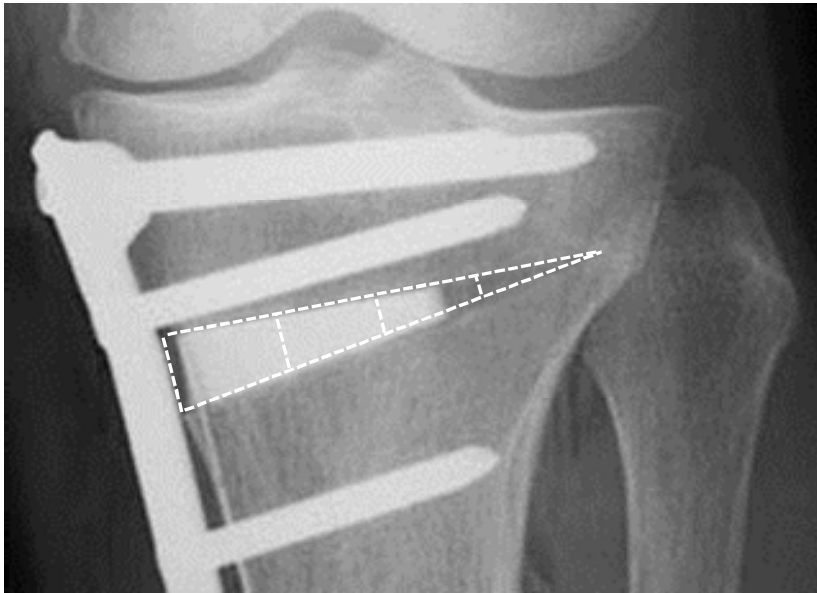
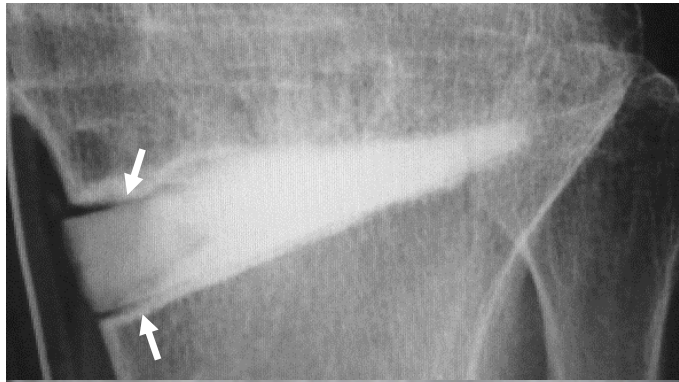
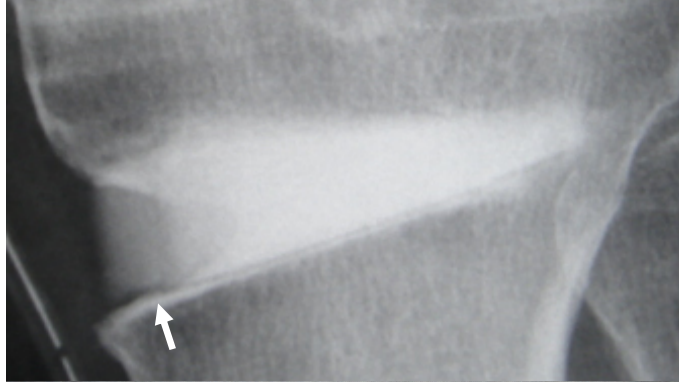


Figure 2

2 points



3 points



4 points



5 points

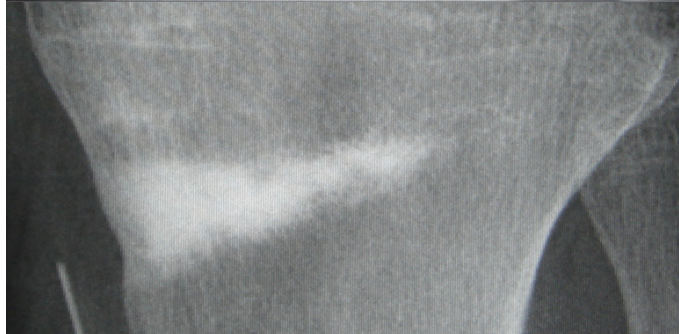


Figure 3



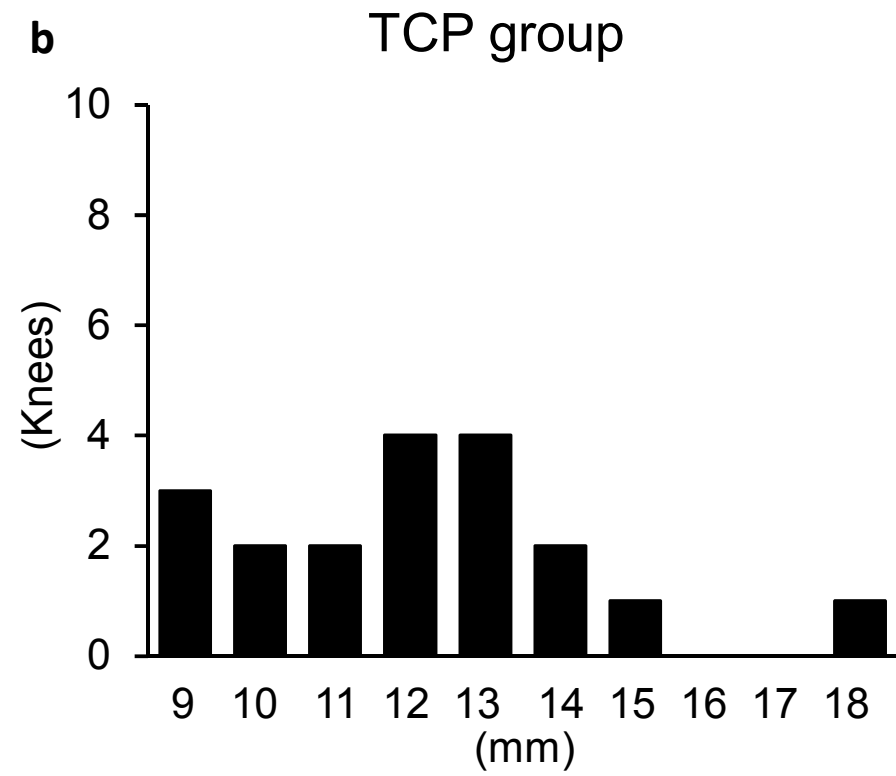
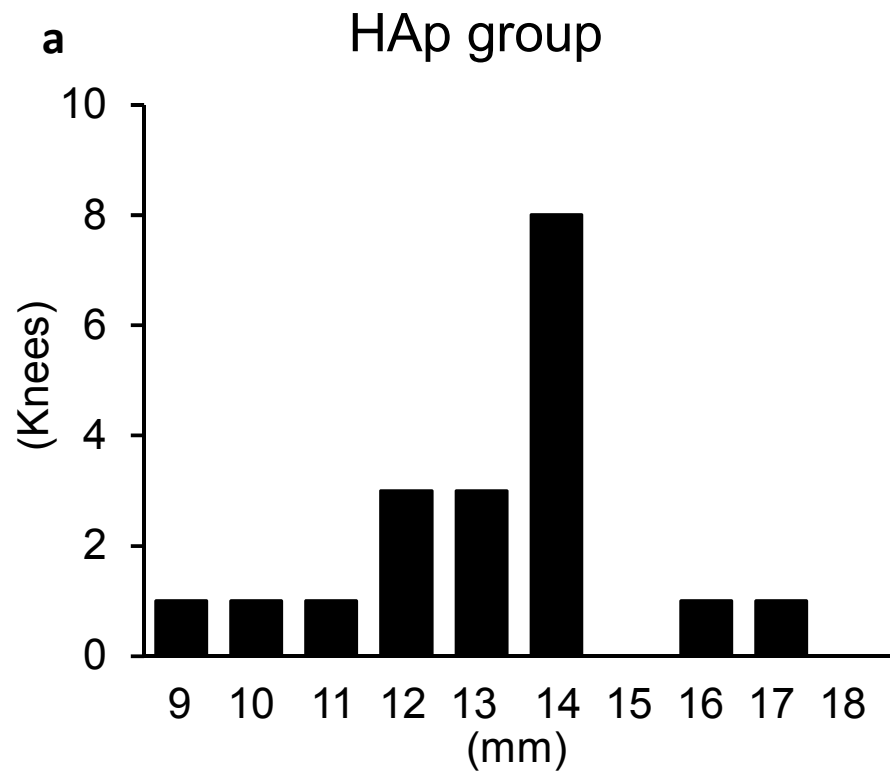
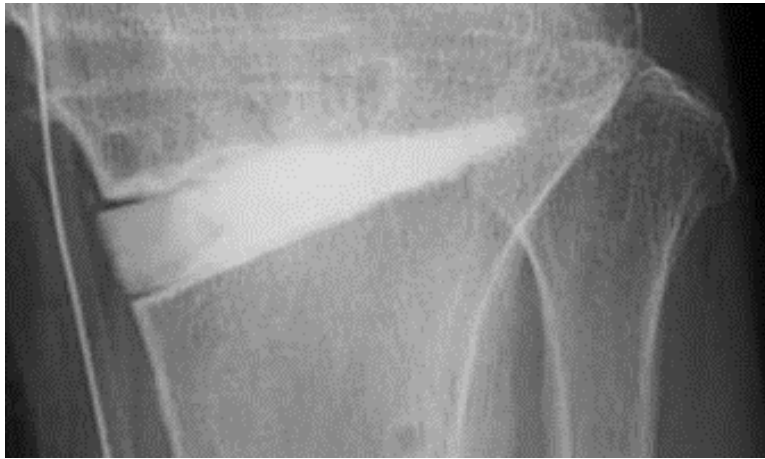


Figure 4



HAp group



TCP group

Figure 5

Table 1.

Biomaterial characteristics of both ceramics

	HAp	TCP
Chemical formula	$\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$	$\text{Ca}_3(\text{PO}_4)_2$
Compressive Strength (MPa)	12	20
Porosity (%)	75	60
Macropore (micrometer)	100–300	100–400
Micropore (micrometer)	none	~5

Table 2.

Background factor of patients

	HAp group	TCP group	p value
Age (years)	61.0 (7.0)	60.5 (5.9)	n.s.
Male/Female (patients)	5/14	2/17	n.s.
Height (cm)	156.3 (7.6)	155.6 (9.6)	n.s.
Weight (kg)	69.2 (15.3)	67.6 (14.3)	n.s.
BMI (kg/m <sup>3</sup> )	28.3 (5.2)	27.8 (4.4)	n.s.
YAM (%)	88.3 (16.7)	92.9 (11.7)	n.s.

Mean (Standard deviation)

Table 3.

Comparisons of preoperative status of the patients

	HAp group	TCP group	p value
Ext. angle (°)	4.5 (5.7)	3.9 (5.9)	n.s.
Flex. angle (°)	140.4 (7.9)	140.8 (11.8)	n.s.
JOA score (points)	65.6 (8.4)	67.3 (8.6)	n.s.
OA grade (patients)			n.s.
Grade 0	0	0	
Grade 1	0	0	
Grade 2	8	8	
Grade 3	11	10	
Grade 4	0	1	
FTA (°)	180.1 (3.1)	179.4 (3.8)	n.s.
WBL (%)	26.4 (13.0)	27.7 (12.0)	n.s.
Tibial slope (°)	9.1 (3.6)	7.2 (3.4)	n.s.
Insall-Salvati ratio (%)	0.8 (0.1)	0.9 (0.2)	n.s.
Entire leg length (mm)	741.3 (38.0)	732.3 (19.6)	n.s.

Table 4.

Comparison of postoperative alignment immediately after surgery

	HAp group	TCP group	p value
Opening angle (°)	11.2 (3.2)	10.4 (3.5)	n.s.
Opening distance between the osteotomy sites (mm)	13.5 (1.7)	12.5 (2.4)	n.s.
FTA (°)	168.9 (2.6)	169.0 (2.1)	n.s.
Tibial slope (°)	13.7 (4.7)	11.4 (3.7)	n.s.
Insall-Salvati ratio (%)	0.8 (0.1)	0.9 (0.2)	n.s.

Table 5.

Comparison of postoperative clinical results of HTO

	HAp group	TCP group	p value
Ext. angle (°)	1.6 (4.1)	2.2 (4.9)	n.s.
Flex. angle (°)	143.2 (7.9)	141.4 (8.5)	n.s.
JOA score (points)	91.1 (10.4)	93.5 (6.6)	n.s.
FTA (°)	169.8 (2.8)	169.8 (2.9)	n.s.
WBL (%)	69.0 (8.8)	70.5 (14.6)	n.s.
Tibial slope (°)	13.7 (3.9)	11.5 (4.5)	n.s.
Insall-Salvati ratio (%)	0.9 (0.1)	0.9 (0.1)	n.s.
Entire leg length (mm)	747.0 (41.4)	739.3 (29.5)	n.s.