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ORIGINAL ARTICLE

# Pie-crusting technique is effective and safe to release superficial medial collateral ligament for total knee arthroplasty

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**KEYWORDS**
Pie-crusting;
Soft tissue balance;
Superficial medial collateral ligament;
Total knee arthroplasty

**Abstract** *Background:* Pie-crusting technique is a damage-control soft tissue balance skill of total knee arthroplasty (TKA). The outcome of this technique to release lateral soft tissue is reasonable. A limited number of studies have focused on medial collateral ligament release with pie-crusting technique in the past years because of concerns about its efficacy and safety.
*Method:* All cases underwent superficial medial collateral ligament (SMCL) release with either pie-crusting technique or traditional technique (39 knees in each group) between January 1, 2014 and August 31, 2015. A comparison study between two techniques was performed; meanwhile, 23 patients (26 knees) in pie-crusting group were followed up. Data including knee function, radiographic result and complications were analysed.
*Results:* Comparison study demonstrates that pie-crusting technique can achieve a comparable or even better effect of alignment correction. Data of follow-up patients are reasonable. The mean postoperative flexion contracture is $1.2 \pm 3.6°$. The mean postoperative motion arrange is $104.0 \pm 14.4°$. The mean postoperative hospital for special surgery knee score point is $82.0 \pm 7.4$ points. The mean postoperative femoral tibial angle is $172.4 \pm 2.0°$. The level of joint line elevates around $2.1 \pm 1.9$ mm. There are four knees that use brace after operation, and none of them present unstable knee. No severe complication has been reported, and most patients were satisfied with life quality.
*Conclusions:* Using pie-crusting technique to release SMCL for TKA is effective and safe.
*The translational potential of this article:* Although pie-crusting technique has been used in TKA for years, it is seldom chosen to release medial collateral ligament, especially to release

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SMCL, which is a vital step of malalignment correction. This study aims to evaluate the efficacy and safety of this technique in total knee arthroplasty patients.


## Introduction

Malalignment of lower extremities can usually be corrected after osteotomy of femur and tibia in total knee arthroplasty (TKA), while some cases still present an unbalanced joint gap, which may be caused by chronic soft tissue disease, trauma and iatrogenic impairment [1–4].

To correct an unbalanced joint, different soft tissue release techniques were developed. Among these techniques, traditional release technique, which is also called Insall release technique, has become a popular method to release contracture soft tissue with an acknowledgeable clinical outcome reported by sufficient studies [1,5–8]. However, some studies also show their concerns about complications brought by this technique, which include unstable knee due to overrelease, elevation of joint line, which may affect track of patella and haemarthrosis caused by periarticular arterial injuries [4,9–12].

As a damage-control method, pie-crusting technique is translated from arthroscopy surgery, and it aims to reduce complications of arthroscopic operation [13,14]. At first, this new technique is usually performed to release lateral tissue for patients who suffer a stiff iliotibial tract or lateral collateral ligament [15–19]. Compared with lateral knee, releasing medial soft tissue can make a much greater biomechanical contribution to keep whole system stable [6]. Recently, a few studies focus on medial collateral ligament release with pie-crusting technique and report comparatively inspired clinical results [20–23].

In this study, we release superficial medial collateral ligament (SMCL) with pie-crusting technique and evaluate it in both clinical effect and safety perspectives. A comparison study between traditional technique and pie-crusting technique as well as a short-term follow-up study for pie-crusting release cases are involved. We expect our study can demonstrate that releasing SMCL with pie-crusting technique is effective and safe.

## Patients and method

### Ethics statement

This study is a retrospect study. No extra clinical interference (e.g. surgical, pharmaceutical, physical) will be performed during the whole study. All patients involved in this study have been informed that their record might be used and published. The privacy of patients will be protected. This study has obtained the permission of ethical committee of Peking University. The ethical number is: IRB00006761-2016064.

### Patients

All patients underwent TKA between January 2014 and August 2015. All operations and perioperational tests were taken in Peking University Third Hospital.

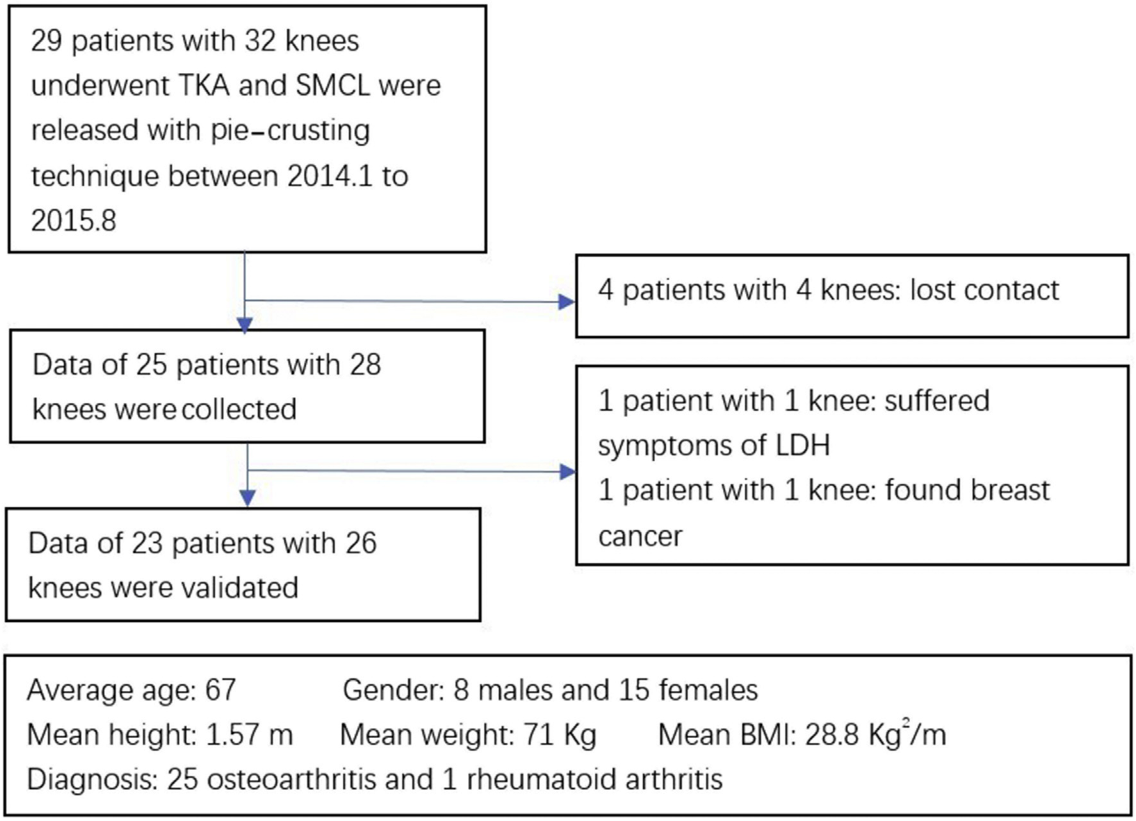
Pie-crusting group includes 36 patients (10 males and 26 females) with 39 knees. Average age is 66 $\pm$ 8.7Y (48–86Y) and mean height, weight and body mass index (BMI) are 1.57 $\pm$ 0.10 m (1.47–1.80 m), 71 $\pm$ 11.3 Kg (58–111 Kg) and 28.8 $\pm$ 3.9 kg/m$^2$ (22.4–34.3 kg/m$^2$), respectively. As for cases in traditional release group, 38 patients (4 males and 34 females) with 39 knees are involved. Average age is 67 $\pm$ 6.4Y (54–78Y), and corresponding mean height, weight, BMI are 1.54 $\pm$ 0.15 m (1.41–1.69 m), 71 $\pm$ 17.8 Kg (43–101 Kg) and 28.1 $\pm$ 4.8 kg/m$^2$ (16.6–39.5 kg/m$^2$), respectively.

In pie-crusting release group, 29 patients (32 knees) who underwent release with a release scalpel (a curve-handle is designed that blade can be kept perpendicular to ligament tissue when releasing) were followed up after TKA. After a period of 10.4-month follow-up, data of 23 patients (8 males and 15 females) with 26 knees were collected, and all cases were diagnosed as osteoarthritis except 1 knee (rheumatoid arthritis). At the terminate point, data of 6 patients were excluded (4 patients lost contact, 1 patient suffered a severe low back pain because of lumbar disc herniation and 1 patient was unfortunately diagnosed with breast cancer), and data of 23 patients with 26 knees were validated (Picture 1).

### Surgery procedure

Genesis II posterior stabilised high flexion implants (Smith and Nephew, London, UK) was used in all cases.

After tourniquet is inflated, articular was exposed with a standardised medial parapatellar approach. Patella was dislocated, and infrapatellar fat pad was dissected. Anterior cruciate ligament and residue meniscus was dissected, and patella tendon was released. Femur osteotomy with a valgus cut of 6° was performed with protection of both lateral and medial collateral ligaments. Tibia osteotomy was performed with a posterior tilt cut of 3° after dissection of posterior cruciate ligaments. The data of removed bone thickness of distal femur and proximal tibia were collected, and size of prosthesis is measured. A spreader was inserted into joint gap to evaluate soft tissue condition. If joint gap presented unbalance with a narrow medial gap, SMCL would be released with pie-crusting technique or traditional release technique (details will be described in next section). Femoral and tibial component would be installed after obtaining a balanced joint gap and component sizing confirmation. An appropriate plate would be inserted between components. Then, stability and motion of knee with both flexion and extension was reassessed and confirmed. If medial tissue remained

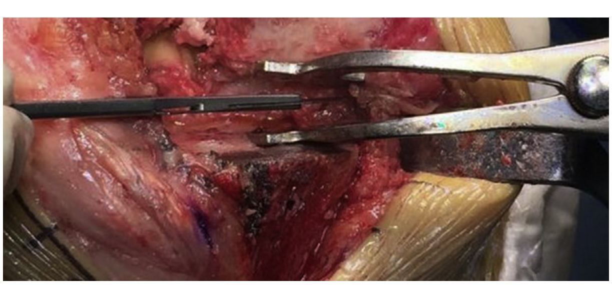



**Picture 1** Flow chart of follow-up study: six patients with six knees were excluded since correspondent reason.
TKA = total knee arthroplasty; SMCL = superficial medial collateral ligament; LDH = lumbar disc herniation.

contracture, posterior—medial capsule would be released. Both components were fixed with bone cement. Patella surface was remolded without installing patella component. Closure procedure was performed with standard method.

## Release technique

SMCL was released in all cases of this study. For pie-crusting technique, 3 to 5 small incisions at mid-substance of ligament were pricked by a scalpel or a needle, and contracture gap would be released gradually with a spreader simultaneously (Picture 2). The release range should be controlled between 2 and 5 mm. Tension and width of joint gap was reassessed with spreader after the first release. If medial side remained tense, then SMCL would be released



**Picture 2** Pie-crusting SMCL with a release scalpel: a spreader was inserted into unbalanced gap, and a trapezium zone with narrow medial side could be observed.
SMCL = superficial medial collateral ligament.

again. The second release should be performed beside the first release location. This step might process more than once until a balanced joint gap was obtained. As for traditional release technique, tibial insertion of SMCL was partially released. Standard and other steps resemble pie-crusting technique.

## Radiographic study

Femoral tibial angle (FTA) was compared between two groups before and after TKA separately. Furthermore, data of follow-up patients were evaluated in perspectives which included FTA, femoral component angle, tibial component angle, and joint line level.

## Function evaluation

For follow-up patients, knee function was evaluated before surgery and at terminate point of follow-up in flexion contracture, range of motion and hospital for special surgery knee score (HSS).

## Patient administered questionnaire

For follow-up, a questionnaire was posed to patients to evaluate life quality, satisfaction level of surgery and complication incidence. Questions like brace wearing, pain around knee (level and location) as well as knee function were involved.

Table 1 Comparison study between Pie-crusting technique and traditional technique.

| Comparison items | Pie-crusting (n = 39) | Tradition (n = 39) | *p* |
|---|---|---|---|
| Age (Y) | 66 ± 8.7 (49–86) | 67 ± 6.4 (54–78) | 0.543 |
| Gender (M/F) | 10/26 | 4/34 | 0.077 |
| Height (m) | 1.57 ± 9.6 (1.47–1.80) | 154 ± 15.4 (1.41–1.69) | 0.355 |
| Weight (Kg) | 71 ± 11.3 (58–111) | 71 ± 17.8 (43–101) | 0.994 |
| BMI (Kg/$m^2$) | 28.8 ± 3.92 (22.4–34.3) | 28.1 ± 4.77 (16.6–39.5) | 0.472 |
| Preoperational FTA (degree) | 184.6 ± 5.76 (169.0–195.1) | 184.3 ± 4.86 (166.4–184.1) | 0.786 |
| Postoperational FTA (degree) | 174.4 ± 1.76 (171.6–179.7) | 175.3 ± 2.36 (169.5–183.1) | 0.045* |
| Plate thickness (mm) | 11 (11–13) | 11 (9–11) | 0.014* |
| Femur osteotomy (mm) | 9 (9–10) | 9 (9–10) | 0.295 |
| Tibia osteotomy (mm) | 9 (9–10) | 9 (9–9) | 0.018* |

BMI = body mass index, FTA = femoral tibial angle.
**p*-value is less than 0.05.
Postoperational FTA means the degree Femur-Tibia Angle which can reflect the anatomical condition of lower limbs. In normal condition, it should precent a slight valgus. FTA should be between 170 degree and 180 degree.
Plate thickness means the thickness of the plate inserted into joint gap. It can reflect the width of joint gap. A thicker plate means a wider gap.
Tibia osteotomy means the width that tibia we cut off. We observe osteotomy volume and plate thickness to see the change of joint gap. In this article, the difference of osteotomy fits in difference of plate thickness, which means soft tissue release does not affect width of joint gap obviously.

### Others

Data of osteotomy at distal femur and proximal tibia and thickness of plate in both groups had been recorded, and a comparison was made between groups.

### Statistics

Data of age, height, weight, BMI and FTA between groups were analysed by independent *t* test. Gender difference was analysed by Chi-square test. Data of osteotomy and plate thickness were analysed by quartile method. A *p* value less than 0.05 is regarded as a statistical difference. Statistics software used is SPSS 22.

## Results

### Comparison study

There is no difference between two groups in age, gender, height, weight and BMI before TKA. Radiographic data present no difference in preoperation FTA. Compared with traditional release group, pie-crusting group shows a smaller postoperation FTA ($p = 0.045$), which indicates a greater valgus degree. Both tibia osteotomy volume and plate thickness are greater in pie-crusting group than in traditional group ($p = 0.018$ and $p = 0.014$, respectively), and correspondent data of femur show no difference between two groups (Table 1).

Table 2 Knee function of follow-up cases.

| Time point | Pre-operation | Terminal time point |
|---|---|---|
| Flexion contracture (degree) | 13.5 ± 10.6 (0–40) | 1.2 ± 3.6 (0–15) |
| Range of motion (degree) | 81.0 ± 19.2 (40–110) | 104.0 ± 14.4 (65–130) |
| HSS (point) | 61.2 ± 6.4 (49–72) | 82.0 ± 7.4 (63–92) |

### Follow-up data analysis

Knee function parameter of follow-up cases presents an obvious improvement at terminal follow-up point compared with that before surgery in terms of flexion contracture, range of motion and HSS points (Table 2).

Results of patient administered questionnaire (PAQ) show that four of 26 patients were recommended to use a brace after surgery to prevent instability of knee, and these four cases have taken off brace without symptom and sign of unstable knee. There is one case that reports a severe pain around patella which limits daily activities including walking and climbing stairs. Besides, there are five cases that experienced moderate degree pain without influencing daily life. Except the case with severe pain, two other cases report difficulty when negotiating stairs because of flexion contracture (10 and 15°). No haemarthrosis is reported during follow-up period (Table 3).

Table 3 Patient administered questionnaire at the end of follow-up.

| Evaluation factors | Patient/knee | Ratio (%) |
|---|---|---|
| Knee brace usage | 4/26 knees | 15.4 |
| Knee instability | 0/0 knees | 0 |
| Moderate pain | 5/26 knees | 19.2 |
| Pain affect daily activity | 1/26 knees | 3.8 |
| Pain in release section | 0/26 knees | 0 |
| Haemarthrosis | 0/26 knees | 0 |
| Negotiating stairs without difficulty | 19/23 patients | 82.6 |
| Walking without difficulty | 22/23 patients | 95.6 |

**Table 4** Radiographic results of follow-up cases.

| Measurements | Preoperation | Terminal time point |
|---|---|---|
| FTA (degree) | 184.1 ± 6.3 (169–194) | 172.4 ± 2.0 (172–178) |
| Femoral component angle (degree) | NA | 91.8 ± 1.4 (90–95) |
| Tibial component angle (degree) | NA | 88.9 ± 1.3 (87–92) |
| Joint line level (mm) | 17.2 ± 2.4 (12–24) | 19.3 ± 2.9 (14–26) |

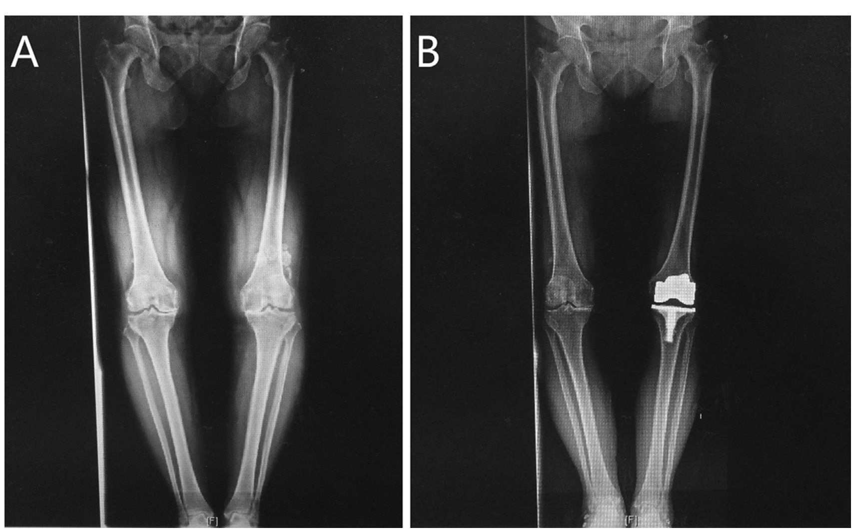
FTA = femoral tibial angle.
Since radiographic standard of terminal point (3 patients take in different clinic) is not as strict as preoperation (all patients take in PUTH), precision of individual data will be set as unit digit.

Radiographic result presents a reasonable correction of FTA, and both femoral component angle and tibial component angle locates in normal range. Level of joint line elevates approximate 2 mm after surgery (Table 4). Radiographic image of a 21-month follow-up case is provided (Picture 3).

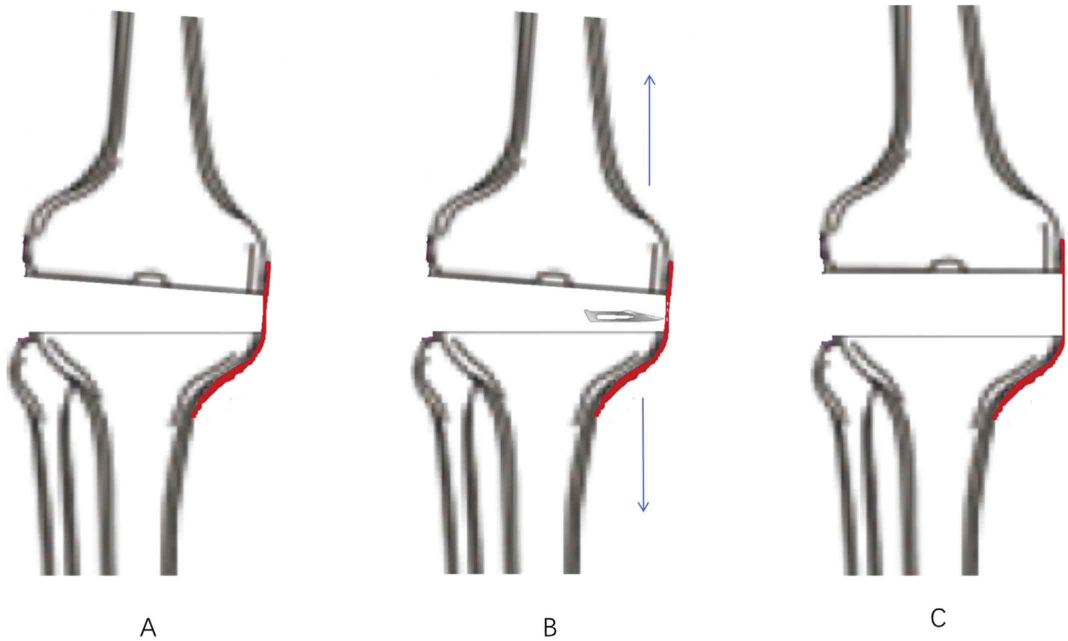
## Discussion

Generally speaking, abnormal alignment correction depends on two main surgical procedures: osteotomy and soft tissue balance technique. Although femoral and tibial osteotomy plays a crucial role of TKA, knees with severe varus or valgus malformation cannot be corrected without soft tissue release. Traditional technique aims to release ligament—bone insertion, which maintains original quality of ligament. Many studies have demonstrated its effect while some disadvantages are also present [5–8]. Instability of knee due to overrelease is the most concerned problem, which may convert a valgus knee to varus or vice versa [4,10–12]. Compared with medial collateral ligament insertion at femur side, Sharpey fibre structure formats tibial insertion, which may not provide sufficient strength when ligament is overreleased from bone [23]. In addition, haemarthrosis can be induced because of direct injury of arteries or aneurysm rupture induced by low power injury [24]. Besides that, joint line elevation may obstruct track of patellar by inappropriate release [25]. Thus, a less invasive and more controllable technique is required. Compared with traditional technique, pie-crusting technique focuses on mid-substance of ligament, which avoids ligament—bone insertion—related complications. More importantly, a series of small incisions can release tense tissue progressively (Picture 4).

Data of comparison study present a reasonable result that indicates pie-crusting technique can achieve a comparable or even better effect of alignment correction. Although pie-crusting group shows better result of post-operation FTA with a statistical difference, data of traditional technique also locate in a satisfactory range. Compared with the difference of the average value, the smaller standard deviation of pie-crusting group should be more meaningful, which indicates this technique is more controllable and precise. We also notice that thicker bone was cut from proximal tibia, and thicker plates were selected for pie-crusting group. For this phenomenon, the difference of plate thickness mainly attributes to different thickness of tibia osteotomy which mostly depends on scale of joint damage. For these knees, we may prefer to choose pie-crusting technique to prevent overrelease because traditional technique may make joint gap too loose to keep the knee stable. In addition, thickness of osteotomy in all cases is in the normal range, and a 2-mm difference does not affect treatment outcomes and our study results. Knees with thicker plates were also protected with brace, and no complication was reported.




**Picture 3** Radiographic comparison between preoperation and terminate point of follow-up (21 months after surgery): FTA has been corrected from 192° to 178°. Joint line level has changed from 11 mm to 8 mm. Femoral component angle is 91° and tibial component level is 89°. (A) preoperation; (B) 21 months after operation.
FTA = femoral tibial angle.




**Picture 4** Scheme of pie-crusting technique. (A) Unbalanced joint gap with SMCL contracture; (B) SMCL is released with some small incisions; (C) a balanced joint gap is obtained after release. Red line: SMCL. Blue arrow: direction of release force. Wright square: incision.
SMCL = superficial medial collateral ligament.

In this study, we presume that scalpel is more controllable than needle because tube structure of needle and slope of needlepoint cannot standardise the size of each incision. Besides that, a curve-handle design can help in keeping scalpel perpendicular with ligament to find a release standard. Patients who underwent pie-crusting release with this scalpel were followed up, and data were collected and analysed in different aspects. Meftah et al. [26] combined different information into a PAQ form which could reflect subjective responses directly. In our study, we design a PAQ form with some improvements that are more suitable for Chinese patients. According to results of PAQ form, 95.6% patients can walk without difficulty, and 82.6% patients can climb stairs. Only three knees remained flexion contracture with 5, 10 and 15°, respectively, which might be due to insufficient release of medial–posterior capsule, not SMCL. At the terminal point of follow-up study, range of motion and HSS point present an obvious improvement. Radiographic results also show that FTA remains in a reasonable range with good position of femoral and tibial component. All results indicate a satisfactory release effect of pie-crusting technique.

As a soft tissue release manoeuvre, risk of overrelease will be considered as the major problem even though pie-crusting technique was designed to reduce the ratio of this complication. Some studies suggested that pie-crusting technique should be used at safe areas such as lateral tissue and deep medial collateral ligament [6,15–19]. They also suggest acting with caution when releasing SMCL because it can affect alignment remarkably and sensitively [18,27,28]. These concerns are understandable because there is no agreed standard of incision size, interval distance between two incisions, initial release location and gauge of release tools [5,20]. Nevertheless, Verdonk et al. [21] compared pie-crusting technique and traditional method for releasing SMCL and reported no difference between two techniques in both effectivity and safety perspectives. Meneghini et al. [28] performed a biomechanical test which presented a stair-shape decrease of tissue stiffness in pie-crusting model, instead of a collapse presented in traditional technique model. In addition, a broader mid-substance area of SMCL is more suitable for pie-crusting technique than other tissue. In our study, four knees were protected with a brace in concern of knee instability due to greater bone volume of osteotomy and thicker plates insertion. No unstable sign presented during operation, and these knees are stable without braces during motion at the end of follow-up.

For other complications studied in PAQ, pain was seldom observed in the early stage after surgery. Most of cases relieved progressively, and four knees still complained a light-level pain at the end of follow-up. Only one knee suffers a severe pain around patellar at terminal point, which is not related to the release section. No haemarthrosis is reported because of good exposure of SMCL in TKA. An approximate 2 mm elevation of joint line can be observed from X-ray. This elevation lies in an acceptable range, and it left no influence on patella track which could be confirmed by negative result of no thumb test.

There are many limitations to our study. First, in some of cases, there is lack of measurement of joint gap which can dynamically reflect change of gap width during the process of release. As radiographic test cannot evaluate contributions of osteotomy and soft tissue balance technique to correct alignment separately, as a direct evidence, width and tense of joint gap in each release step is valuable.

Fortunately, we observe that if soft tissue release is required, osteotomy usually makes very limited contribution to alignment correction, which acknowledges the value of radiographic result as validate indirect evidence. Furthermore, navigation system can provide dynamic data with remarkable accuracy and precision, which should be imported in future study [29]. Second, it would be more convincible if there were more patients involved. On one hand, it is a new technique performed in our institution, and the number of cases presented an increased trend in 2015 compared with 2014, where more cases can be expected in future studies. On the other, we selected cases that underwent TKA with Genesis II posterior stabilised high flexion implants which require cutting off posterior cruciate ligament during operation to reduce its influence on release procedure. Third, we only followed up patients in pie-crusting group because traditional release technique has been regarded as a classical method, and its effect and safety has been demonstrated by sufficient studies. Nevertheless, it is not reasonable to neglect treatment outcome of any patient, and we will collect their data in mid-term and long-term follow-up studies.

In summary, compared to traditional release technique, pie-crusting technique has following advantages: First, as a damage-control technique, pie-crusting technique is more controllable and precise. Second, pie-crusting technique will not hurt the tendon bone insertion. In addition, we release SMCL from inside to outside. There is no important nerve and vascular passes through the superficial side of SMCL. Thus, less vascular and nerve injuries are induced. Unlike translation of biomaterial or drug, this study focuses on surgical technique translation which also plays a crucial role in translational medicine. As a damage-control release technique, the effect and safety of pie-crusting technique is promising; some further studies such as release standard founding, tool design and long-term follow-up are worth to practice.

## Conflicts of interest statement

None of the authors have financial interests related to this study to disclose.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jot.2018.01.001.

## References

[1] Engh GA. The difficult knee: severe varus and valgus. Clin Orthop Relat Res 2003;416:58–63.
[2] Mihalko WM, Whiteside LA, Krackow KA. Comparison of ligament-balancing techniques during total knee arthroplasty. J Bone Joint Surg Am 2003;85(Suppl.):132–5.
[3] Whiteside LA. Soft tissue balancing: the knee. J Arthroplasty 2002;17(Suppl. 1):23–7.
[4] Cameron HU, Hunter GA. Failure in total knee arthroplasty. Mechanisms, revision, and results. Clin Orthop Relat Res 1982; 170:141–6.
[5] Elkus M, Ranawat CS, Rasquinha VJ, Babhulkar S, Rossi R, Ranawat AS. Total knee arthroplasty for severe valgus deformity: five to fourteen years follow-up. J Bone Joint Surg Am 2004;86:2671–6.
[6] Elkus M, Ranawat CS, Rasquinha VJ, Babhulkar S, Rossi R, Ranawat A. Total knee arthroplasty for severe valgus deformity. J Bone Joint Surg Am 2005;87(Suppl.):271–84.
[7] Teeny SM, Krackow KA, Hungerford DS. Primary total knee arthroplasty in patients with severe varus deformity: a comparative study. Clin Orthop Relat Res 1991;273:19–31.
[8] Karachalios T, Sarangi PP, Newman JH. Severe varus deformities treated by total arthroplasty. J Bone Joint Surg Br 1994;76:938–42.
[9] Schwarzkopf R, Hadley S, Abbasi M, Meere PA. Computer-assisted surgery patterns of ligamentous deformity of the knee: a clinical and cadaveric study. J Knee Surg 2013;26: 233–8.
[10] Del Gaizo DJ, Della Valle CJ. Instability in primary total knee arthroplasty. Orthopedics 2011;34:519–21.
[11] Wyss T, Schuster AJ, Christen B, Wehrli U. Tension controlled ligament balanced total knee arthroplasty: a 5-year results of a soft tissue orientated surgical technique. Arch Orthop Trauma Surg 2008;128:129–35.
[12] Dragosloveanu S, Cristea S, Stoica C, Dragosloveanu C. Outcome of iatrogenic collateral ligaments injuries during total knee arthroplasty. Eur J Orthop Surg Traumatol 2014;24: 1499–503.
[13] Agneskirchner JD, Bernard M, Lobenhoffer P. Verbesserte Ubersicht bei arthorskopischen eingriffen am innenmeniskushinterhorn durch perkutanes needling des innenbandes. Artroskopie 2005;20:75–7.
[14] Agneskirchner JD, Lobenhoffer P. Arthroscopic meniscus surgery: technical operative methods. Unfallchirurg 2004;107: 795–801.
[15] Mullaji AB, Padmanabhan V, Jindal G. Total knee arthroplasty for profound varus deformity: technique and radiological results in 173 knees with varus of more than 20 degrees. J Arthroplasty 2005;20:550–61.
[16] Aglietti P, Lup D, Cuomo P, Baldini A, De LL. Total knee arthroplasty using a pie-crusting technique for valgus deformity. Clin Orthop Relat Res 2007;464:73–7.
[17] Clarke HD, Fuchs R, Scuderi GR, Scott WN, Insall JN. Clinical results in valgus in total knee arthroplasty with the "pie crust" technique of lateral tissue releases. J Arthroplasty 2005;20: 1010–4.
[18] Mihalko WM, Krackow KA. Anotomic and biomechanical aspects of pie crusting posterolateral structure for vagus deformity correction in total knee arthroplasty: a cadaveric study. J Arthroplasty 2000;15:347–53.
[19] Clarke HD, Scuderi GR. Lateral ligament release for valgus deformity in primary total knee arthroplasty. Tech Knee Surg 2003;2:74.
[20] Bellemans J. Multiple needle puncturing: balancing the varus knee. Orthopedics 2011;34:510–2.

[21] Verdonk PC, Pernin J, Pinaroli A, Ait SST, Neyret P. Soft tissue balancing in varus total knee arthroplasty: an algorithmic approach. Knee Surg Sports Traumatol Arthrosc 2009;17:660—6.

[22] Bellemans J, Vandenneucker H, Van LJ, Victor J. A new surgical technique for medial collateral ligament balancing: multiple needle puncturing. J Arthroplasty 2010;25:1151—6.

[23] Lui P, Zhang P, Chan K, Lin Q. Biology and augmentation of tendon-bone insertion repair. J Orthop Surg Res 2010;5:59.

[24] Saksena J, Platts AD, Dowd GSE. Recurrent haemarthrosis following total knee replacement. Knee 2010;17:7—14.

[25] Seo JG, Moon YW, Kim SM, Park SH, Lee BH, Chang MJ, Jo BC. Prevention of pseudo-patella baja during total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2015;23:3601—6.

[26] Meftah M, Blum YC, Raja D, Ranawat AS, Ranawat CS. Correcting fixed varus deformity with flexion contracture during total knee arthroplasty: the "inside-out" technique. J Bone Joint Surg Am 2012;94:e66.

[27] Fakioglu O, Ozsoy MH, Ozdemir HM, Yigit H, Cavusoglu AT, Lobenhoffer P. Percutaneous medial collateral ligament release in arthroscopic medial meniscectomy in tight knees. Knee Surg Sports Traumatol Arthrosc 2013;21:1540—5.

[28] Meneghini RM, Daluga AT, Sturgis LA, Lieberman JR. Is the pie-crusting technique safe for MCL release in varus deformity correction in total knee arthroplasty? J Arthroplasty 2013;28:1306—9.

[29] Liu X, Li JS, Li G. Application of computer-assisted imaging technology in human musculoskeletal joint research. J Orthop Transl 2014;2:8—15.