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2D versus 3D templating in total knee arthroplasty☆

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ABSTRACT

Background: Preoperative digital templating in total knee arthroplasty (TKA) helps to determine the need of non-standard implants, prophesies the bony resections and helps to anticipate the intraoperative plan. Templating within the process of patient specific instrumentation (PSI) is fairly new and 2D planning has not been compared to PSI templating.
Methods: 94 patients underwent unilateral primary TKA with magnetic resonance imaging (MRI) based preoperative templating and PSI cutting blocks. Parallel to this, three observers templated all cases using digital planning on standard preoperative x-rays. The examiners templated all cases independently and were blinded to the component sizes used intraoperatively.
Results: Three-dimensional (3D) templating was accurate in predicting the correct implant size in 100% of the cases. The femoral and tibial two-dimensional (2D) digital templating varied from 43.6% to 59.5% and 52.1% to 68% of the cases. When allowing ±1 difference, femoral 2D digital templating varied from 93.6% to 97.8% of the cases and ranged from 94.6% to 98.9% on the tibial side. All observers show "very good" correlation. The coefficient indicates a very good agreement in between the three observers.
Conclusion: 3D templating has very high accuracy for the actual implant size prediction. Compared to this, 2D digital templating is an accurate method to approximately (±1 size) determine the size of TKA components. However, we judge this technique accurate enough, that 2D templating allows launching Template-directed instrumentation (TDI), while the examiner does not need a high level of clinical experience.
Clinical relevance: Within the process of digital planning, the surgeonmight focus evenmore on the upcoming operation.

1. Introduction

Preoperative digital templating in total knee arthroplasty (TKA) becomes more and more relevant as it helps to determine the need of non-standard implants, prophesies the bony resections and helps to anticipate the intraoperative plan [4,12]. Traditionally preoperative templating was performed with acetate templates on standard anterior–posterior and lateral radiographs of the knee [2]. The variability in image quality and radiograph magnification might compromise the accuracy and reproducibility of this method [4]. Further development led to the widespread use of the picture archiving and communication system (PACS). This trend increased the development and use of radiography and templating software packages. The objectives of digital templating are to improve the preoperative planning in order to reduce intraoperative errors concerning implant sizing, alignment and fit, as well as giving the opportunity to prepare excess components for the operation room. A cost effective consequence would be a reduction of the used surgical trays in the operation room when this so called Template-directed instrumentation (TDI) is exerted [3] or the utilization of size specific single use instruments. Several studies with focus on the accuracy of digital templating have been conducted before and proved its efficacy for the approximate prediction of the implant size [2,4,10,12–14]. One study showed that the training level has no effect on accuracy of digital templating in primary TKA [4].

Templating within the process of patient specific instrumentation (PSI) is fairly new. Previous studies reported outliers when magnetic resonance imaging (MRI)- or computed tomography (CT)-based patient-specific instrumentation was used [5,13]. Accordingly the accuracy of PSI templating has not been evaluated sufficiently and two-dimensional (2D) planning has not been compared to PSI templating.

Due to this lack of knowledge we performed this study in order to answer the following questions: (1) How accurate was MRI based PSI templating concerning the actual size of the femoral and tibial component?; (2) How accurate was 2D preoperative templating concerning the actual size of the femoral and tibial component?; (3) Is 2D templating accurate enough to launch TDI?; (4) Is there an effect of training level on the accuracy in digital 2D templating?

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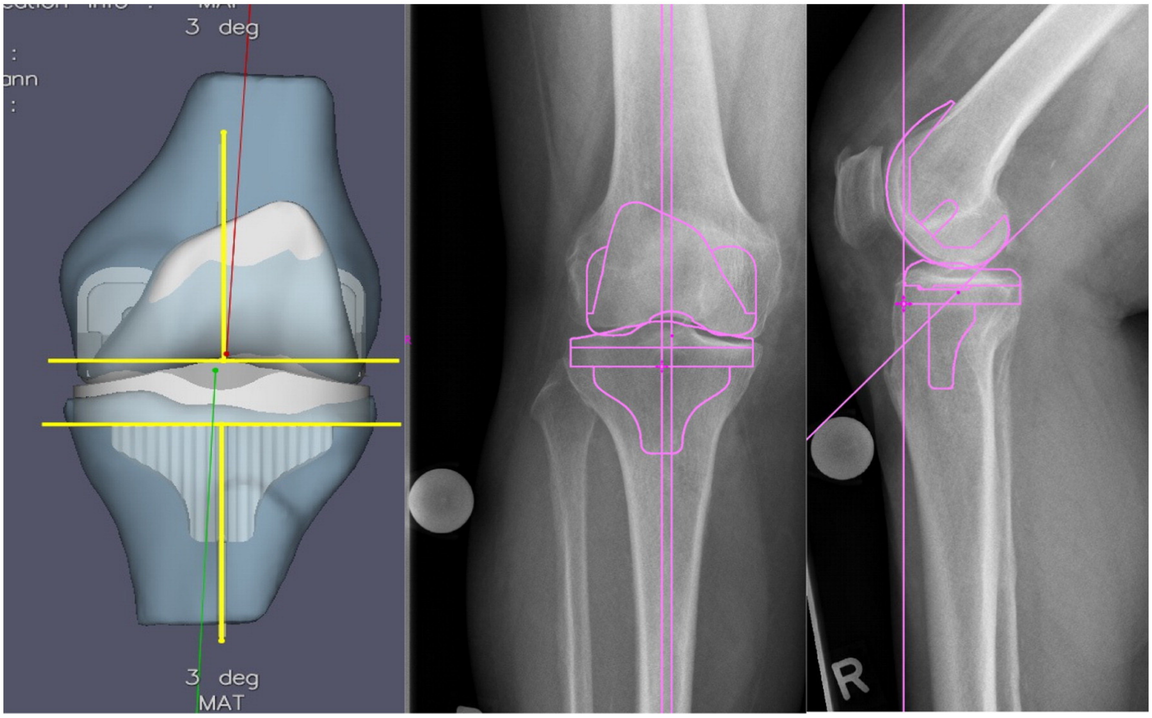

Fig. 1. On the left side 3D planning. A preoperative plan, that was reviewed and approved by the surgeon, including the component sizes was provided. The PSI cutting blocks were produced on this basis. On the right side 2D planning: OrthoView digital planning software (OrthoView LLC, Jacksonville, Florida) was used.

2. Material and methods

Between 01/2012 and 01/2013 94 patients underwent unilateral primary TKA with MRI based PSI cutting blocks using the Stryker/Otismed ShapeMatch Technology. Patients were 67 ± 8.0 years old (SD), the cohort contained of 60 men and 34 women with a body mass index (BMI) of 30 ± 4.3 (SD). Three experienced surgeons at a high volume university hospital performed all procedures. The measurement data was collected prospectively. Only patients with primary osteoarthritis were included in this study. Deformities > 3° of varus or valgus were excluded.

All patients received an MRI of the knee according to the manufacturer's protocol. A preoperative plan, that was reviewed and approved by the surgeon, including the component sizes was provided. The PSI cutting blocks were produced on this basis.

All TKAs were implanted via a medial parapatellar approach. The cemented femoral and tibial components (Triathlon Stryker Orthopedics, Mahwah, NJ) and patient-specific femoral and tibial cutting blocks (ShapeMatch Stryker Orthopedics, Mahwah, NJ; Fig. 1) were used on all knees.

Preoperative radiographs were performed using standardized protocols one day preoperatively with a 25 mm metallic ball in order to have a calibrating marker. Radiographs included an anterior–posterior view, a lateral view, a long-leg view and a patellar tangential view. One senior surgeon (T.C.), one fourth year resident (M.E.) and one first month resident (P.P.) templated all cases using OrthoView digital planning software (OrthoView LLC, Jacksonville, Florida; Fig. 1). The examiners templated all cases independently and were blinded to the component sizes used intraoperatively.

An Excel sheet (Microsoft Co., Redmond, WA) was used to prospectively collect the data. Data analysis was performed using GraphPad Prism software (GraphPad Prism Software Inc, San Diego, CA). Figures were prepared using the GraphPad Prism software (GraphPad Prism Software Inc, San Diego, CA). The Pearson Coefficient (r), a dimensionless measure of the strength of the linear relationship between two quantitative variables, was calculated in order to evaluate the interobserver and the intraobserver coefficients (Table 1) [9]. Frequency distribution analyses were performed as well.

Table 1
Coefficients and level of agreement.

0 = poor
0–0.2 slight
0.2–0.4 fair
0.4–0.6 moderate
0.6–0.8 substantial
0.8–1 very good

Table 2
The intraobserver coefficients femur and tibia.

Correlation	Actual size femur vs. senior surgeon	Actual size femur vs. 4th year resident	Actual size femur vs. 1st month resident
r	0.83	0.81	0.85
95% conf. int.	0.75–0.88	0.73–0.87	0.78–0.89
Correlation	Actual size tibia vs. senior surgeon	Actual size tibia vs. 4th year resident	Actual size tibia vs. 1st month resident
r	0.90	0.86	0.91
95% conf. int.	0.85–0.93	0.79–0.90	0.87–0.94

Table 3
The interobserver coefficients femur and tibia.

Correlation femur	Senior surgeon	4th year resident	1st month resident
Senior surgeon		0.93	0.92
4th year resident	0.93		0.90
1st month resident	0.92	0.90	
Senior surgeon		0.93	0.92
4th year resident	0.93		0.90
1st month resident	0.92	0.90	

Table 4
Frequency distribution femur.

	Senior surgeon	4th year resident	1st month resident
Accurate	51	41	56
1 larger	20	34	6
1 smaller	17	15	30
2 larger	1	3	0
2 smaller	5	1	2

Table 5
Frequency distribution tibia.

	Senior surgeon	4th year resident	1st month resident
Accurate	60	49	64
1 larger	14	24	8
1 smaller	17	16	21
2 larger	0	1	1
2 smaller	3	4	0

3. Results

Reliability: The intraobserver coefficients for the three observers are shown in Table 2. All observers show "very good" correlation to the actual size. The interobserver coefficients are shown in Table 3. The coefficients indicate a very good agreement in between the three observers.

Accuracy: The three-dimensional (3D) templating was accurate in predicting the correct implant size in 100% of the cases. The femoral 2D digital templating varied from 43.6% to 59.5% of the cases (Table 4). When allowing ± 1 difference, femoral 2D digital templating varied from 93.6% to 97.8% of the cases (Table 4). The tibial 2D digital templating varied from 52.1% to 68% of the cases (Table 5). When allowing ± 1 difference, tibial 2D digital templating varied from 94.6% to 98.9% of the cases (Table 5). Analyzing the cases where the difference to the actual implant was more than about two sizes, we found a strong correlation to the projection quality of the preoperative x-rays.

4. Discussion

This study is the first to compare the reliability and accuracy of 2D and 3D templating for the Stryker Triathlon knee system. The MRI based templating protocol used for this system proved to be a highly reliable method to predict component sizes in TKA. In 100% of the cases the predicted implant sizes were used in the operation and judged to be appropriate. Outcomes of this study are comparable to the results presented by Issa et al. who showed reproducible results for the same MRI based procedure [5]. In contrast to that are the results of Kobayashi et al. and Stronach et al., who report an accuracy around 50% concerning component sizes [8,13]. This might be due to different data processing, templating procedures (CT/MRI) and TKA systems.

This 3D technique proved to be highly accurate in our study and thus has the ability to achieve the goal of a higher cost effectiveness by reducing instruments and processes. It still has the limitation of a high preoperative planning expense. Thus, 2D digital templating must still be considered as a standard before performing a TKA [6,7,11].

Previous studies showed that 2D templating is a reliable and reproducible tool with an accuracy above 90% when a discrepancy of ± 1 size is tolerated [1,14]. This is consistent with our data for the Triathlon System. Hsu et al. performed a cost analysis study were the OrthoView digital planning software (OrthoView LLC, Jacksonville, Florida) was used to determine the two most likely tibial and femoral component sizes of the NexGen CR Flex TKA system (Zimmer, Warsaw, IN) for each case. This sizing information was used to direct component vendors to prepare three lightweight instrument trays based on these sizes. In 97% of the cases the prepared sizes determined by TDI using three instrument trays were sufficient. The overall use of trays and costs were drastically reduced [3].

Our data indicate, that templating of the femoral component is less accurate. In only approximately half of the cases, the correct implant size was predicted. This was equally described by Trickett et al. before and might be due to the different diameter of the medial and lateral femoral condyle. The bony landmarks are more difficult to detect during the templating process [14]. This is especially true, if the projection quality of the x-rays is altered, as could be shown in our data. So in conclusion, a precise projection is necessary for accurate preoperative templating, especially for the femoral component.

In our study three different observers with different levels of clinical experience performed the templating of the component sizes. The observers' experience level had no influence on the data of this study. Intraobserver reliability among the examiners in this study is comparable to other studies, where observers with varying experience performed the examinations as well [4].

There are limitations to be addressed: (1) Patients with deformities $>3°$ of varus or valgus were excluded. Greater deformities might have an influence on the accuracy of preoperative templating. (2) The small number of examiners might have influenced the outcome of this study. Nevertheless, each examiner was educated with the software in the same way and was blinded to the actual outcome. (3) The quality of the x-ray may have influenced our results. Analyzing the cases where the difference to the actual implant was more than about two sizes, we found a strong correlation to the projection quality of the preoperative x-rays.

In summary, 3D templating proofed to have very high accuracy for the actual implant size prediction. Compared to this, 2D digital templating is an accurate method to approximately (± 1 size) determine the size of TKA components, but can only predict the actual implant in about 50% of the cases. Within the process of digital planning, the surgeon might focus even more on the upcoming operation. However, we judge this technique accurate enough, that 2D templating allows launching TDI to reduce overall costs, while the examiner does not need a high level of clinical experience.

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