ORIGINAL PAPER

The impact of femoral bone quality on cementless total hip pre-operative templating

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Abstract

Introduction Accurate templating is an integral part of pre-operative planning for total hip arthroplasty (THA). Templating of cementless implant accuracy has been average. The aim of this study was to assess the impact of Dorr femoral classification on the accuracy of pre-operative digital templating.

Patients and methods This was a retrospective study of cementless THA pre-operative planning using one implant design. A total of 210 primary THA were reviewed. A total of 102 cementless THAs matched the exclusion and inclusion criteria, using one implant combination, were analyzed by an orthopaedic resident and a fellowship trained arthroplasty surgeon. Each x-ray was evaluated and assigned a femoral Dorr classification. Accuracy of templating was determined by comparing the templated size with the actual implant size both for the femoral and acetabular components.

Result Out of the 102 cases, exact templating size was achieved in 35.3% for the acetabulum, 25.5% for the femur, and only in 9.8% for both components. Reasonable templating, ± one of the actual size, was achieved in 78.4% for the acetabulum, 74.5% for the femur, and 60.8% for both components. Use of Dorr femoral type classification did not result in better templating accuracy.

Conclusion Pre-operative hip cementless templating using digital x-rays with double marker method do not improve accuracy compared to other methods available for templating. Accounting for bone quality using the Dorr femoral classification did not improve accuracy.

Keywords Dorr classification · Templating · Total hip arthroplasty

Introduction

Pre-operative planning in THA consists of careful history and physical examination along with radiographic evaluation [1]. Detailed preplanning is a prerequisite of correct approach, implant position, and fixation choices leading to a successful and reproducible hip arthroplasty. Templating the hip component may aid in achieving correct offset and leg length. Manual templating had high accuracy rates with cemented implants and lower rates in cementless implant designs [2, 3]. According to the literature, digital templating with a reference ball did not improve accuracy in cementless hip arthroplasty [4, 5]. Patient characteristics such as age, gender, and BMI did not have an impact on templating accuracy in studies performed [5–7].

The Dorr femoral classification infers femoral bone quality based on plain hip x-rays.

The aim of this study was to assess the impact of Dorr femoral classification on the accuracy of pre-operative digital templating.

Patients and methods

This was a retrospective study of cementless THA preplanning using one implant design. After receiving institutional review board approval, we reviewed all hip arthroplasties performed in our department between January 2020 and November 2020. A total of 210 primary hip arthroplasties cases were reviewed. Inclusion criteria were all cementless cases (both acetabular and femoral components). Exclusion

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criteria included operations performed through anterior approach, operations using a different cementless design, THA for neck of femur fracture, severe deformity, poor-quality pre-operative x-rays, and x-rays performed without the calibration device. We collected demographic data included age, gender, side of operation, body mass index, previous steroid therapy, and chronic renal failure. Surgical data included surgical approach, implant name, and size. A total of 102 cases met our exclusion and inclusion criteria.

All surgery in this study were performed using the posterior approach with Trilogy and Avenir (both Zimmer Biomet, Warsaw, IN) implants.

All x-rays were taken using the same technique: supine antero-posterior (AP) radiographs using the Kingmark® calibration device (BrainLAB, Feldkirchen, Germany) according to the manufacturer's specifications and a "frog" lateral view without a calibration marker.

All cases were analyzed and reviewed by an orthopaedic resident and a fellowship trained arthroplasty surgeon. Each x-ray was evaluated and assigned a femoral Dorr classification as described by Dorr et al. [8]. Templating was performed using the TraumaCad™ software (BrainLAB, Feldkirchen, Germany). Accuracy of templating was determined comparing the templated size with the actual implant size both for the femoral and acetabular components.

Statistical analysis

The reliability between the two observers, the junior and the senior, was assessed via the intra-class correlation coefficient (ICC) analysis using single measure, two-way mixed, absolute-agreement parameters [9]. Point estimates of the ICC are interpreted as poor reliability (< 0.5), moderate reliability (0.5 to 0.75), good reliability (0.75 to 0.90), and excellent reliability (> 0.9) [10]. Simple linear regression models were fitted to predict the associations between participant's characteristics and the difference between raters mean value and actual results. All significant variables at alpha level of 0.2 were entered to multivariable linear regression model. A p-value < 0.05 was considered statistically significant. All reported p-values are two-tailed. Analysis was done using the IBM SPSS STATISTICS, version 25.0 (Inc., Chicago, IL, USA) and R statistical software version 3.5.0 (R Project for Statistical Computing).

Results

A total of 102 cementless THAs using one implant combination were reviewed. The average age and BMI were 66.9 (range 40–89) and 28.7 (range 17.64–43.06), respectively. Sixty-four were female and 38 male patients, 62 were right sided and 40 left. Osteoarthritis was the reason for surgery in 87 patients, avascular necrosis in eight, rheumatoid arthritis in four, and developmental dysplasia of the hip in three. Only three patients were chronically treated with steroids and three had chronic renal failure.

When the implant size was the same as the templated size, it was described as "exact," and when the templated size was ± one size (one numeric difference in the femur and 2-mm difference in the acetabulum), it was described as "reasonable." When the templated size was ± three sizes, it was described as an "outlier."

Senior surgeon exact templating size was achieved in 35.3% for the acetabulum, 25.5% for the femur, and only in 9.8% both components were templated correctly.

Resident exact templating size was achieved in 36.3% for the acetabulum, 26.5% for the femur, and 11.8% for both components.

Senior surgeon reasonable templating was achieved in 78.4% for the acetabulum, 74.5% for the femur, and 60.8% for both components.

Resident reasonable templating was achieved in 74.5% for the acetabulum, 73.5% for the femur, and 55.9% for both components.

Senior surgeon outlier templating was 6.9% for the acetabulum and 2.0% for the femur.

Resident outlier templating was 4.9% for the acetabulum and 5.9% for the femur.

Interobserver reliability showed acceptable reliability between the senior and junior templating results and is described in Table 1.

Univariable analysis indicated a relationship may exist between gender and templating accuracy (p-value 0.022, standard error 0.41), but this was refuted in a multivariable analysis (p-value 0.113, standard error 0.02).

Dorr classification

There was a moderate agreement between senior surgeon and resident with regard to Dorr classification as seen in Table 2. No case existed where it was rated as Dorr class A by one and Dorr type C by the second.

In both the senior surgeon and the residents' Dorr classification, the femoral component size was smaller for type A, larger for type B, and largest for type C as seen in Table 3.

Table 1 Interobserver reliability estimated by intra-class correlation (ICC)

	ICC	
	Template acetabulum	Template femur
Junior-senior	0.727	0.901
Junior-actual	0.768	0.730
Senior-actual	0.818	0.838

Table 2 Distribution of Dorr classification between senior surgeon and junior resident

		Senior			Total
		A	B	C	
Junior	A	15	8	0	23
	B	8	61	1	70
	C	0	6	3	9
Total		23	75	4	102

Kappa: 0.489 — moderate agreement

Table 3 Dorr classification and mean femoral implant sizes

Dorr_classification			Mean	Standard error
A	Junior	Templated size	3.261	0.301
		Actual size	3.174	0.321
	Senior	Templated size	2.130	0.301
		Actual size	2.826	0.321
B	Junior	Templated size	4.129	0.173
		Actual size	3.714	0.184
	Senior	Templated size	3.547	0.167
		Actual size	3.880	0.178
C	Junior	Templated size	5.111	0.481
		Actual size	4.889	0.514
	Senior	Templated size	4.250	0.722
		Actual size	5.250	0.771

For both raters, the average femoral size was close to size three in Dorr class A, size four in Dorr class B, and five in Dorr class C.

Dorr classification subcategories were not associated with increased templating accuracy.

In each of the Dorr classification subcategories, there was a difference in the error tendency between the senior surgeon and the resident. The senior surgeon tended towards a smaller size whereas the residents error tended towards a larger size as shown in Figs. 1 and 2.

Discussion

Preoperative templating evolved alongside THA. Initially solid templates over pelvis x-rays with a pre-requisite magnification were used. Knight and Atwater reported significant differences between estimated magnification and measured post-operative magnification. They reported exact acetabular templating in 62% of cases and exact femoral templating in 78% of cemented cases. Cementless femoral templating exact accuracy was only 42% [11]. Eggli et al. reported excellent accuracy rates of 92 and 90% for the femoral acetabular components respectively. Their study had mostly cemented implants [2]. Digitalization brought a perceived more accurate method of magnification calibration and software programs were supposed to lead to better templating. Yet, analogue methods yielded better results [4, 12] and cementless hip templating did not achieve accuracy levels of cemented hip templating [3, 4]. Ball calibration marker, used in digital x-rays, should be placed at the coronal plane of the hip and improper placement may lead to erroneous magnification calibration. A double marker method, as used in this study, eliminates the need to guess the proper coronal hip plane. However, Warshcawski et al. found no difference in templating accuracy between a single calibration ball marker and a double marker method [13].

We were able to achieve exact templating using only one cementless implant device in 35% of acetabuli and 25% of femori and being exact in both components only in 10%

Fig. 1 Junior resident actual vs templated size according to Dorr classification. 1: Templated size, 2: actual size
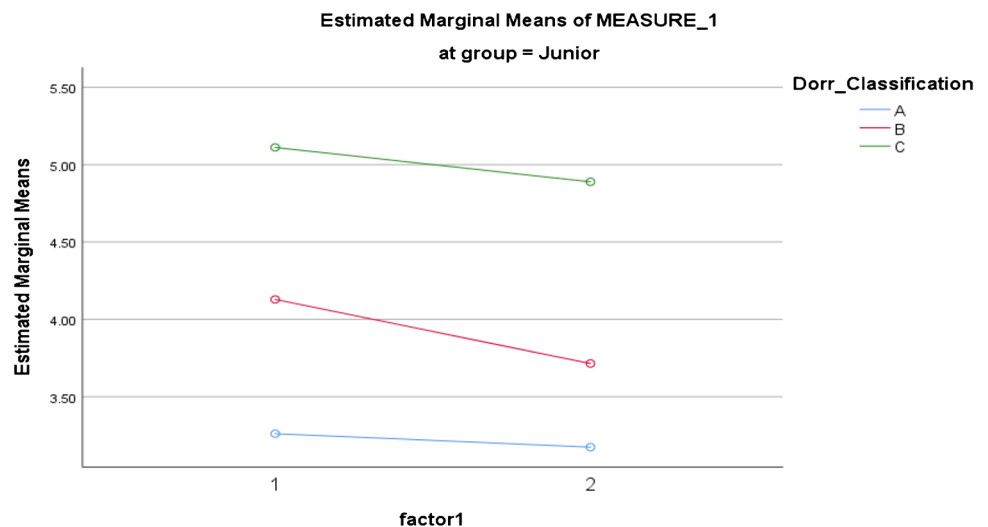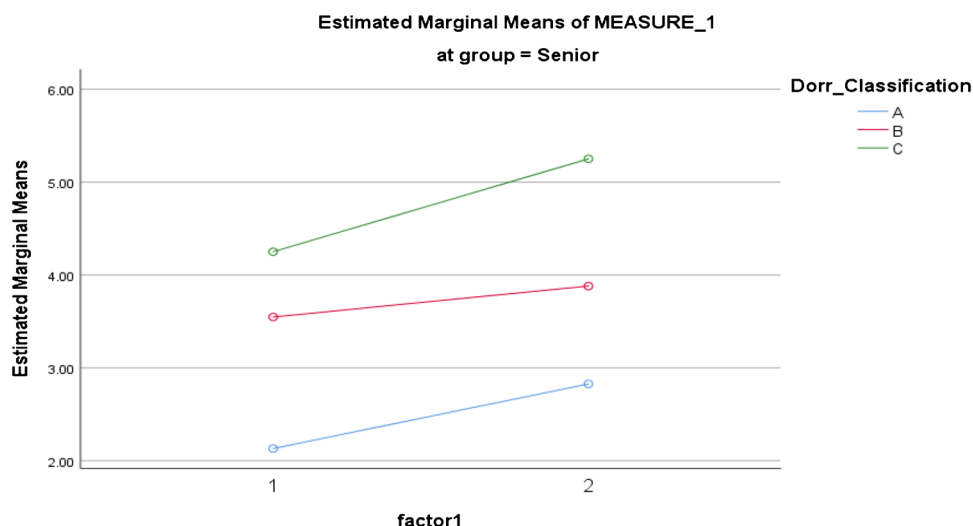
Fig. 2 Senior surgeon actual
vs templated size according to
Dorr classification. 1: Tem-
plated size, 2: actual size

of cases. If one accepts a reasonable accuracy to include sizes ± one, the accuracy improves to 78%, 74%, and 60% for the acetabuli, femori, and both components respectively. These results are similar to other reports of cementless templating accuracy and significantly lower than those reported for cemented implants [2, 5, 6, 11]. Still, cementless fixation is becoming more common worldwide [14–16]. Cemented implants' surgical technique is more forgiving, relying on a cement mantle between the implant and bone for fixation. This technique is affected less by bone quality. Different cementless femoral designs exist, for example: press fit design mandating diaphyseal cortical contact, dual tapered fully coated relying on cancellous bone contact — are affected by bone quality. As shown in other studies, our study could not find a significant statistical correlation between demographic patients' characteristics and cementless hip templating accuracy.

Dorr et al. in their study from 1993 tried to correlate roentgenographic patterns with femoral bone characteristic [8]. Type A bone consisted of thick cortices and a narrow diaphyseal canal with a funnel-shaped proximal femur. Type B bone exhibited loss of medial and posterior bone. Type C bone had dramatic thin cortices and a very wide canal often referred to as a "Stovepipe" shape. Later studies evaluated the Dorr's classification reproducibility and found an interobserver reliability kappa coefficient of 0.3–0.6 [17, 18]. In our study, the kappa coefficient between the senior and resident was fair at 0.489.

Our assumption was that using Dorr femoral classification may improve accuracy. Dorr type A femori with thick cortices and narrow canal may prove difficult to accommodate the templated femur resulting in a smaller implant while Dorr type C femur with soft, thin cortices may not offer

adequate fixation leading to a larger implant insertion. Dorr type B femur, not too thin and not too stiff, might result in good accuracy between the templated implant and the one used. Our assumption was not corroborated. We did not find a Dorr classification with better templating accuracy. The difference between Dorr classification manifested itself by increase in average femoral size of one size for every classification, type A averaging close to size three, type B close to size four, and type C close to five.

Conclusion

Pre-operative hip cementless templating using digital x-rays with double marker method do not improve accuracy compared to other methods available for templating. Accounting for bone quality using the Dorr femoral classification did not improve accuracy.

Declarations

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