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Original Article

Anatomy Section

A Cross-sectional Observational Study on Distal Femoral Morphometry in West-central Maharashtra, India

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ABSTRACT

Introduction: Femur or thigh bone is the longest bone of the human skeleton. The lower end of the femur articulates with the tibia to form the knee joint. Femur shows morphometric variations in relation to geography, race, ethnic group, and gender.

Aim: To measure various dimensions of the lower end of the femur in West-central Maharashtra, India.

Materials and Methods: A cross-sectional observational study was conducted in the Department of Anatomy, Armed Forces Medical College, Pune, Maharashtra, India from May 2010 to May 2013 on 280 adult dried femora (136 Right and 144 Left). The lower ends of the femora were evaluated for bicondylar width (BCW), anteroposterior diameter of both medial and lateral condyles, the transverse diameter of both medial and lateral condyles, intercondylar notch width, notch width index, and femoral aspect ratio. All the measurements of the right and left femur were obtained by Vernier caliper and recorded separately. The data was analysed statistically using student's t-test. The p-value <0.05 was considered statistically significant.

Results: The mean bicondylar width for the right and left-side were 72.83±5.09 mm and 71.83±5.65 mm, respectively. Medial condyle anteroposterior diameter (MCAPD) for right and left femur were 56.99±3.79 mm and 55.20±4.35 mm. Lateral condyle anteroposterior diameter (LCAPD) for right and left femur were 57.48±4.96 mm and 56.37±4.55 mm. Medial condyle transverse diameter (MCTD) for right and left-side were 23.68±2.68 mm and 23.63±2.40 mm. Lateral condyle transverse diameter (LCTD) for right and left-side were 25.26±2.56 mm and 25.24±2.62 mm. Intercondylar notch width (ICNW) for right and left-side were 21.06±2.45 mm and 21.00±2.62 mm. Notch width index for right and left femur were 0.29±0.03 and 0.29±0.03. The Femoral Aspect Ratio (FAR) for right and left-side was 1.27±0.07 and 1.28±0.05, respectively. In this study, there were no statistically significant differences between values of right and left-sides except, medial condyle anteroposterior diameter showed a statistically significant difference between the two sides (p=0.0002).

Conclusion: The morphometric data collected from the lower end of the femur indicated ethnic variations with a different populations in India and abroad. Values obtained in the present study were less than the dimensions of commonly available femoral implants because the design of most of these implants is based on dimensions of foreign populations, indicating size mismatch. These data will aid in the decision-making and implant design, suitable for local population.

Keywords: Bone, Femur, Implants, Knee joint, Osteoarthritis, Prosthesis, Tibia

INTRODUCTION

The femur is the longest and most proximal bone of the lower limb. Its rounded, smooth head form a hip joint with an acetabulum. The medial and lateral condyles present in the distal expanded end of the femur articulate with condyles of the tibia to form the knee joint [1]. Anteriorly, the femoral condyles are separated by smooth articular patellar surfaces. Posteriorly, the condyles are much more prominent and are separated by a deep intercondylar notch [2,3]. The morphometric measurements of the femoral condyles show regional variations among populations and these variations are related to genetic and environmental factors. Variations in the human skeletal measurements determine the racial characteristics of the populations [4].

The morphometric data of lower end of femur has an important role in medicolegal cases and identification of sex. The measurements are used for decision making during total knee arthroplasty [5]. Quantitative knowledge of the various parameters of distal femoral end are critical for understanding the biomechanics of the knee joint [6,7]. Morphometry of the distal femur is also helpful for understanding knee joint functioning [6,8], total knee arthroplasty and surgical navigation [9,10].

An important factor for long-term success of total knee arthroplasty is good shape and size match between the prosthesis and resected surface of the joint [11]. A lot of studies had suggested that the same kind of prosthesis is not suitable for different population [10,11]. It is important to obtain morphometric data to achieve best stability and longevity of implant [12,13]. The use of an undersized component may result in implant loosening, oversized component may lead to neighbouring soft tissues impingement. The use of appropriate component size is therefore pivotal to produce long-term outcome following total knee arthroplasty [14-16].

As far as authors are aware, there is no work carried out with this number of samples for measurement of such a large number of dimensions of lower end of femur. Thus, the present study was planned to measure various dimensions of distal end of femur in West-central region of Maharashtra who's built, physique, habits, genetic makeup and personal life styles are different from that of other population. This information can then be used in the designing and development of implants suited for local population as well as assisting in decision-making during clinical practices [17,18].

MATERIALS AND METHODS

A cross-sectional observational study was conducted from May 2010 to May 2013 on 280 adult dried femora 136 (Right and 144 Left) available in the Department of Anatomy of three Government Medical Colleges located in West-central region of Maharashtra. Prior approval of Institutional Ethics Committee (IEC) was taken.

Inclusion criteria: All the selected femora were free of damage or deformity and fully ossified indicating adult bones. Each and every femur used in the present study were prepared in the department

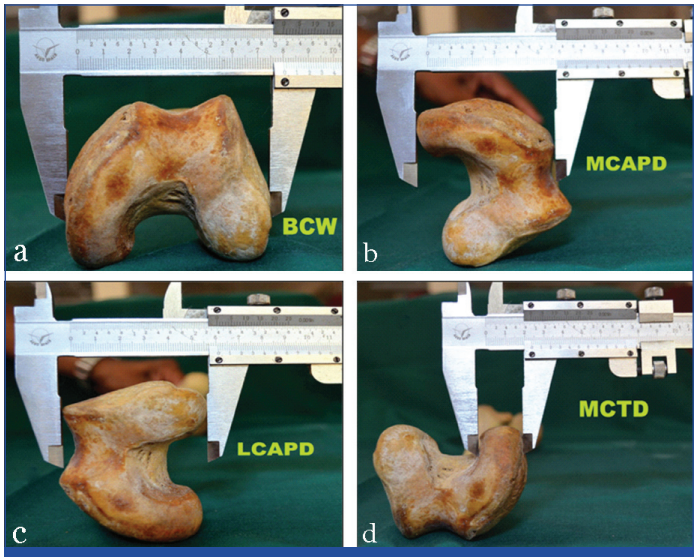
from dissected cadavers obtained from local population. The gender of the bone was not taken into account.

Exclusion criteria: Femora with grossly deformed appearance and pathological changes (fractures, osteophytes, osteoarthritic changes and post mortem damage) were excluded from the study.

Study Procedure

The side of the femora was determined by standard Anatomical procedures. Sliding Vernier calliper was used for taking measurements. All measurements were recorded by single observer for consistency. The measurements were repeated thrice and mean value was taken to minimise error during measurements. The values were recorded in millimetre.

The BCW was measured as maximum distance between medial and lateral epicondyle in transverse plane [Table/Fig-1a] [19,20]. MCAPD was measured as maximum distance between anterior and posterior surface of medial condyle [Table/Fig-1b] [19]. LCAPD was taken as maximum distance between anterior and posterior surface of lateral condyle [Table/Fig-1c] [21,22]. MCTD was measured as maximum distance between medial and lateral surface of medial condyle [Table/Fig-1d] [19]. LCTD was taken as maximum distance between medial and lateral surface of lateral condyle [Table/Fig-2a] [23]. ICNW was measured as maximum distance between medial and lateral surface of intercondylar notch posteriorly [Table/Fig-2b] [17,19,24]. The intercondylar Notch Width Index (NWI) was calculated by dividing intercondylar Notch Width (ICNW) by Bicondylar Width (BCW), the NWI was derived as xy/MN [Table/Fig-2c] [25]. The FAR was calculated by dividing the Bicondylar Width [BCW] with Lateral Condyle Anterior Posterior Diameter [LCAPD], The FAR was derived as MN/KL [Table/Fig-2d] [26-28].



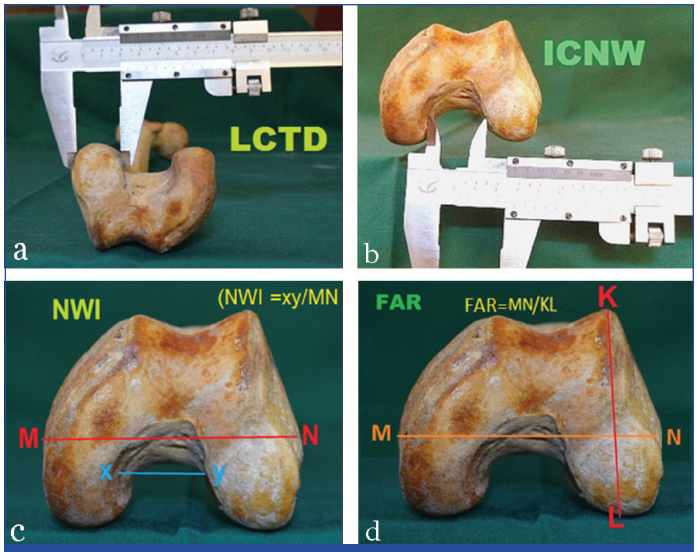
[Table/Fig-1]: (a-d) Measurements of distal end of femur.
BCW: Bicondylar width; MCAPD: Medial condyle anterior posterior diameter; LCAPD: Lateral condyle anterior posterior diameter; MCTD: Medial condyle transverse diameter

STATISTICAL ANALYSIS

All the measurements were tabulated and analysed statistically using Statistical Package for the Social Sciences (SPSS) software version 19.0. Mean and standard deviation for right and left femur was recorded separately. All measurements were rounded to two decimal places. Independent sample t-test was used to find out the differences in the parameters of right and left femur. The p-value <0.05 was considered as significant.

RESULTS

Out of 280 adult dry femur bones, 136 femora belong to right-side and 144 femora to the left-side. Mean anterior posterior diameter of medial condyle was 56.99±3.79 mm on right-side and 55.20±4.35 mm on the left-side. There were no significant differences in various parameters studied in right and left-side (p>0.05) except anterior posterior distance of medial condyle, in which right-side was significantly greater than the left-side (p<0.05) [Table/Fig-3].



[Table/Fig-2]: (a-d) Measurements of distal end of femur.
LCTD: Lateral condyle transverse diameter; ICNW: Intercondylar notch width; NWI: Notch width index; FAR: Femoral aspect ratio; M-N: Bicondylar width; x-y: Intercondylar notch width; K-L: Lateral condyle anterior posterior diameter

S. No.	Parameters	Side of femur bone (mean±SD) (mm)		p-value (2-tailed Student's t-test)
		Right (n=136)	Left (n=144)	
1.	BCW	72.83±5.09	71.83±5.65	0.1204
2.	MCAPD	56.99±3.79	55.20±4.35	**0.0002**
3.	LCAPD	57.48±4.96	56.37±4.55	0.0524
4.	MCTD	23.68±2.68	23.63±2.40	0.8698
5.	LCTD	25.26±2.56	25.24±2.62	0.9486
6.	ICNW	21.06±2.45	21.00±2.62	0.8432
7.	NWI	0.29±0.03	0.29±0.03	0.9999
8.	FAR	1.27±0.07	1.28±0.05	0.9999

[Table/Fig-3]: Mean, Standard deviation and p-value of various parameters of right and left-sides.
BCW: Bicondylar width; MCAPD: Medial condyle anterior posterior diameter; LCAPD: Lateral condyle anterior posterior diameter; MCTD: Medial condyle transverse diameter; LCTD: Lateral condyle transverse diameter; ICNW: Intercondylar notch width; NWI: Notch width index; FAR: Femoral aspect ratio; SD: standard deviation; A p-value <0.05 is considered to be statistically significant

When dimensions of all femoral specimens were considered, the mean bicondylar width 72.31±5.40 was obtained. MCAPD and LCAPD were 56.07±4.18 and 56.91±4.78, respectively. MCTD, LCTD and ICNW were 23.65±2.53, 25.25±2.59 and 21.03±2.53, respectively. Calculated mean NWI was 0.29±0.03 and FAR was 1.27±0.06 [Table/Fig-4].

S. No.	Parameters	N	Range	Mean±SD
1	BCW	280	86.22-58.66	72.31±5.40
2	MCAPD	280	67.48-44.16	56.07±4.18
3	LCAPD	280	88.00-47.20	56.91±4.78
4	MCTD	280	30.79-17.00	23.65±2.53
5	LCTD	280	31.59-18.80	25.25±2.59
6	ICNW	280	29.00-15.28	21.03±2.53
7	NWI	280	0.40-0.20	0.29±0.03
8	FAR	280	1.40-0.80	1.27±0.06

[Table/Fig-4]: Range, mean and standard deviation of various parameters of total femur.
BCW: Bicondylar width; MCAPD: Medial condyle anterior posterior diameter; LCAPD: Lateral condyle anterior posterior diameter; MCTD: Medial condyle transverse diameter; LCTD: Lateral condyle transverse diameter; ICNW: Intercondylar notch width; NWI: Notch width index; FAR: Femoral aspect ratio; SD: standard deviation

DISCUSSION

The morphology of femoral condyles and intercondylar notch play an important role in determining stability of knee joint. Knee joint arthroplasty has gained special position in the management of degenerative diseases of knee joints. Morphometrically matching prosthesis plays a vital role in successful knee arthroplasty [29,30]. The anthropometric data of lower end of femur are very important in designing and selection of proper fitting knee implants. In the present study, values of right and left-side femur were similar (p>0.05) except anterior posterior distance of medial condyle, in which right-side was significantly greater than the left-side (p<0.05). Rajan M and Ramachandran K reported statistically significant difference (p<0.05) in lateral condyle anterior posterior diameter of right and left-side in (right-58.52±3.44, left 56.92±3.4) [31]. Eboh DEO and Igbinedion EN reported statistically significant (p<0.05) bilateral difference in bicondylar width (medial lateral width) of lower end of femur (right- 70.6±8.0, left- 77.0±5.7) [28]. Biswas A and Bhattacharya S observed statistically significant (p<0.05) bilateral variation in medial condyle transverse diameter (right-25.48±2.05, left-27.28±2.29) and intercondylar notch width (right-20.86±2.52, left-19.43±2.57). Devi YE et al., [19], Sivaramalingam S and Gunasekaran SK [33], Vinay G and Vikram S, Terzidis I et al., [7], Ameet KJ and Murlimanju BV [16] and Attada PVK [25] has reported statistically no significant bilateral difference (p>0.05) in parameters of lower end of femur.

In the present study, average bicondylar width was found to be 72.83±5.09 on right-side and 71.83±5.65 on left-side, similar results were obtained by Biswas A and Bhattacharya S [32], Attada PVK [25], Vinay G and Vikram S [22], Rajan M and Ramachandran K [31] in Indian population [Table/Fig-5] and Eboh and Igbinedion EN [28] in foreign population [Table/Fig-6]. The values in the study conducted by Zalawadia AZ et al., [34], Sivaramalingam and Gunasekaran SK [33], Devi YE et al., [19] in Indian population and Wada M et al., [35], Rosenstein AD et al., [36] in foreign population was found to be higher than present study [Table/Fig-5,6]. Not only were present study measurements were smaller than foreign population, but they were also smaller than those of Indian subpopulations. As a result, present study population was significantly at risk for implant overhang and its related complication. The requirement for better fitting implants is vital to guarantee long-term success in total knee arthroplasty.

Author, ethnicity and publication year	BCW		MCAPD		LCAPD		MCTD		LCTD		ICNW		NWI	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Rajan M and Ramachandran K, Chennai, 2020 [31]	72.82± 3.89	71.62± 5.67	56.6± 4.19	57.14± 4.82	58.52± 3.44	56.92± 4.41	22.64± 3.96	23.12± 2.17	22.86± 3.12	23.12± 2.34	21.66± 2.69	21.50± 4.64	-	-
Devi YE et al, Imphal, 2022 [19]	75.34± 5.86	74.94± 6.67	57.29± 4.94	56.39± 5.40	59.44± 4.99	58.04± 4.10	21.62± 2.84	22.24± 2.89	23.29± 3.05	23.76± 2.24	22.41± 2.97	22.26± 3.77	-	-
Chawre HK et al., Madhya Pradesh, 2018 [17]	69.80	66.23	54.30	56.05	56.0	56.0	25.05	22.17	27.0	23.5	17.94	19.0	-	-
Sivaramalingam S and Gunasekaran SK, Coimbatore, 2020 [33]	74.85± 5.04	73.37± 5.14	53.50± 8.49	50.96± 7.28	52.91± 7.92	52.83± 6.80	32.20± 2.20	31.29± 2.71	32.30± 2.27	31.89± 2.38	21.98± 2.52	21.01± 2.56	-	-
Vinay G and Vikram S, Telangana, 2019 [22]	71.8± 5.91	70.8± 5.95	56.3± 4.73	55.7± 4.38	56.6± 4.4	56.9± 4.26	28.6±3.83	28.1± 3.07	31.1±3.02	30.5± 3.21	21.5± 3.01	21.7± 2.85	-	-
Attada PVK, Visakhapatanam, 2018 [25]	72.8± 10.2	74.7± 10.2	56.1± 9.7	56.2± 9.7	-	-	-	-	-	-	18.7±8.4	18.2± 8.4	0.25	
Zalawadia AZ, Gujarat, 2017 [34]	74.53± 2.34 (male)	67.09± 2.11 (female)	57.49± 2.34 (male)	53.91± 2.05 (female)	59.02± 2.69 (male)	54.82± 2.34 (female)	30.32± 3.88 (male)	27.69± 1.43 (female)	31.65± 1.49 (male)	28.88± 1.39 (female)	21.11± 2.02 (male)	19.35± 2.52 (female)	-	-
Biswas A and Bhattacharya S, West Bengal, 2017 [32]	71.71± 4.50	70.71± 5.25	52.97± 3.77	54.74± 3.85	56.20± 3.36	56.05± 4.29	25.48± 2.05	27.28± 2.29	27.80±2.91	28.03± 2.56	20.86± 2.52	19.43± 2.57	-	-
Present study, Maharashtrian population, 2022	72.83± 5.09	71.83± 5.65	56.99± 3.79	55.20± 4.35	57.48± 4.96	56.37± 4.55	23.68±2.68	23.63± 2.40	25.26±2.56	25.24± 2.62	21.06± 2.45	21.00± 2.62	0.29± 0.03	0.29± 0.03

[Table/Fig-5]: Comparison of dimensions of distal femur of present study with various studies on Indian population [17,19,22,25,31-34].
BCW: Bicondylar width; MCAPD: Medial condyle anterior posterior diameter; LCAPD: Lateral condyle anterior posterior diameter; MCTD: Medial condyle transverse diameter; LCTD: Lateral condyle transverse diameter; ICNW: Intercondylar notch width; NWI: Notch width index; R: Right; L: Left

Author, ethnicity and year of study	BCW		MCAPD		LCAPD		ICNW		NWI		FAR	
	R	L	R	L	R	L	R	L	R	L	R	L
Eboh and Igbinedion EN, Nigeria, 2020 [28]	70.60± 8.1	77.20± 5.70	62.10± 4.20	61.80± 4.30	63.30± 4.90	63.50± 4.10	24.20±2.80	23.60±4.70	-	-	1.12± 0.13	1.21± 0.06
Lakati KC et al., Kenya, 2017 [26]	68.39	68.49	57.98	58.05	61.36	61.08	23.00	23.08	-	-	1.11	1.12
Didia BC et al., Nigeria, 2002 [37]	-	-	-	-	-	-	22.7±7.47	22.1±4.47	-	-	-	-
Wada M et al., Japan, 1999 [35]	80±10.5		-	-	-	-	17.0±5.0		0.22±0.04		-	-
Ewe TW et al., Malaysia, 2009 [27]	65.46±5.0		-	-	59.88±4.8		-	-	-	-	1.09±0.007	
Rosenstein AD et al., USA, 2008 [36]	83.24±4.60		-	-	62.94±3.88		-	-	-	-	-	-
Present study, Maharashtrian population, 2022	72.83± 5.09	71.83± 5.65	56.99± 3.79	55.20± 4.35	57.48± 4.96	56.37± 4.55	21.06± 2.45	21.00± 2.62	0.29± 0.03	0.29± 0.03	1.27± 0.07	1.28± 0.05

[Table/Fig-6]: Comparison of dimensions of distal femur of present study with various studies on foreign population [26-28,35-37].
BCW: Bicondylar width; MCAPD: Medial condyle anterior posterior diameter; LCAPD: Lateral condyle anterior posterior diameter; ICNW: Intercondylar notch width; NWI: Notch width index; FAR: Femoral aspect ratio; R: Right; L: Left

The use of an implant, that is too large in the anterior posterior dimension may result in patellofemoral overstuffing. Preparation of a distal femur for an undersized anterior posterior component may result in significant notching with associated increased risk of fractures around prosthesis [37,38]. Except for the study by Devi YE et al., [19], the majority of the measurements of the anterior posterior diameter of the medial and lateral condyles on the Indian population were in agreement with the present study. In foreign population Eboh and Igbinedion EN [28], Lakati KC et al., [26], Ewe TW et al., [27] and Rosenstein AD et al., [36] reported higher values than present study.

Rajan M and Ramachandran K [31], Devi YE et al., [19], Chawre HK et al., [17] reported values of transverse diameter of medial and lateral condyle similar to present study, whereas Sivaramalingam S and Gunasekaran SK [33], Vinay G and Vikram S [22], Zalawadia AZ et al., [34], Biswas A and Bhattacharya S [32] reported higher values for condyles. Anterior Cruciate Ligament (ACL) tears are extremely common in athletes [37]. The size and shape of femoral intercondylar notch and its relationship with cruciate ligament needs to be considered as important influence on predisposition for ACL injury [39]. Patients with ACL tear have relatively greater depth of the femoral condyle compared with patient with normal ACL [40]. Rajan M and Ramachandran K [31], Sivaramalingam S and Gunasekaran SK [33], Vinay G and Vikram S [22], Zalawadia AZ et al., [34] reported similar values of intercondylar notch width in Indian population [Table/Fig-5]. Eboh and Igbinedion EN [28], Lakati KC et al., [26], Didia BC et al., [37] reported higher values of intercondylar notch width in foreign population [Table/Fig-6].

Femoral notch width index was calculated by dividing intercondylar notch width by bicondylar width. A small NWI has been reported as a predictive factor for anterior cruciate ligament injury and implicated in the higher incidence of anterior cruciate ligament injuries in female athletes [39]. Attada PVK [25] in Indian population and Wada M et al., [35] in foreign population reported smaller values of notch width index than present study [Table/Fig-5,6].

The femoral aspect ratio shows a higher ratio for smaller knees and proportionally lower ratio for larger knees. Risk of implant overhang and its associated complication are significant in population having smaller knees [27]. Eboh and Igbinedion EN [28], Lakati KC et al., [26], Ewe TW et al., [27] reported lower values of femoral aspect ratio in foreign population than present study [Table/Fig-6].

Implants for the replacement of the diseased knee joint were mostly developed by European and American manufacturers, using the morphology of their respective population. These implants come in different sizes to suit the various sizes of their population [6,30]. Because of relatively small built size of our population, local surgeons have a fewer choice of size available for implantation [Table/Fig-7,8]. Knee dimensions in present study were much smaller than their western counterparts. The mean bicondylar width in the present study was 72.31 mm, which was comparatively smaller than those reported in Western population. Therefore, the risk of implant overhang and its associated complications are more in our population.

Specimen/Implant	Femoral aspect ratio [FAR]
Sigma PFC®-DePuy-Synthes	1.06
Genesis II®-Smith-Nephew	1.10
Nexgen® -Zimmer-Biomet	1.13
Diamond®-TianJin ZhengTian Medical Instrument Co. Ltd	1.08
Duracon®-Stryker	1.16
Indus Hiflex®-Orthovasive,India	1.13
Advance®- Wright Medical	1.13
Anthem®-Smith-Nephew	1.10
Femur specimens of present study (n=280)	1.27±0.07

[Table/Fig-7]: Comparison of aspect ratios of implants with femur specimens of present study [26].

Variables	Present study	Dimension of implants
Bicondylar width	72.31 mm	57- 82 mm
Anterior posterior diameter of lateral condyle	56.91 mm	51- 75 mm

[Table/Fig-8]: Comparison of lower end femoral dimensions of present study with available femoral implants.

Limitation(s)

The current study was conducted on only 280 bones and did not make comparisons based on sex. Furthermore, large studies involving multiple bones in different parts of Maharashtra, taking into account sex-based comparisons and integrating radiological modalities, will improve the applicability of the study.

CONCLUSION(S)

Present study illustrates the dimensions of the distal femur in population of West-central Maharashtra. The resulting values indicate ethnic differences between different population groups. The data can help in designing suitable implant for local population, choosing correct implants based on ethnic specification will reduce mismatch and improve postoperative outcome.

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