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**Dr. Sunil Kumar PC**  
Associate Professor and Unit  
Chief, Department of  
Orthopaedic, Mysore Medical  
College and Research Institute,  
Mysore, Karnataka, India

**Dr. Deepak MK**  
Assistant Professor and Unit  
chief, Department of  
Orthopaedic, Mysore Medical  
College and Research Institute,  
Mysore, Karnataka, India

**Dr. Mohan Kumar**  
Post-graduate, Department of  
orthopaedic, Mysore Medical  
College and Research Institute,  
Mysore, Mysore, Karnataka,  
India

**Dr. Jyothish K**  
Post-graduate, Department of  
orthopaedic, Mysore Medical  
College and Research Institute,  
Mysore, Mysore, Karnataka,  
India

**Corresponding Author:**  
**Dr. Mohan Kumar**  
Post-graduate, Department of  
orthopaedic, Mysore Medical  
College and Research Institute,  
Mysore, Mysore, Karnataka,  
India

## Measuring limb length discrepancy using pelvic radiographs: Most appropriate method

**Dr. Sunil Kumar PC, Dr. Deepak MK, Dr. Mohan Kumar and Dr. Jyothish K**

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### Abstract

**Introduction:** Leg length inequality following total hip replacement its still common. In order to reduce limb length inequality, surgeons undertake pre-operative measurements, by preoperative templating and use various forms of intraoperative measurements, including computer navigation. We studied to compare and find out which measurement technique for assessing limb length discrepancy using two different pelvic reference has excellent inter-observer variability using standard antero-posterior radiograph.

**Material and Methods:** 40 patients (40 hips) had their measurement of limb length discrepancy on standard AP radiographs. The measurement was done by two observers one is orthopedic surgeon, and other one is radiologist. Two lines were constructed on each of the radiographs, bisecting the acetabular teardrops, ischial spines. Measurements were taken from these lines to the most conspicuous medial point on the lesser trochanter.

**Results:** For measuring limb length using teardrop as a pelvic reference and lesser trochanter as femoral reference inter-observer agreement for radiological measurements  $\kappa=0.893$  (good agreement) for pre-operative radiographic measurements and  $\kappa=0.813$  (good agreement) for post-operative radiographic measurements. By using ischial tuberosity as a pelvic reference and lesser trochanter as femoral reference inter-observer agreement for radiological measurements  $\kappa=0.723$  (Substantial agreement) for pre-operative radiographic measurements and  $\kappa=0.752$  (Substantial agreement) for post-operative radiographic measurements.

**Conclusions:** Measurement of limb length on radiographs has excellent interobserver reliability with the use of the inter teardrop as a pelvic landmark was a better with measurements to the lesser trochanter. Interobserver variability testing showed less agreement when the ischial tuberosity was used as a pelvic landmark compared with the teardrop.

**Keywords:** Leg length, still common, total hip replacement

### Introduction

Measurable leg length discrepancy (LLD) after total hip replacement is common [1, 2], and when symptomatic can cause patient dissatisfaction and distress [3, 4].

Patients who have symptomatic LLD may have an unstable hip, sciatic nerve palsy or an abnormal gait which may exacerbate back, and joint pain and may require the use of a shoe raise [5, 6]. To minimize LLD preoperative templating is essential to the orthopaedic surgeon for preoperatively evaluating and planning many aspects of a THA. The advantage of templating include accurate prediction of prosthetic size, subsequent optimization of prosthetic longevity, and decrease intraoperative complications [5].

Preoperative templating helps to achieve appropriate offset and limb length equality, which would lead to better abductor muscle function, less limping, and decreased need for walking aids [7]. Although limb lengthening may be required to provide a stable hip [8], a LLD not only is associated with patient dissatisfaction [9], but also is the most common reason for litigation after THA [10]. LLD after THA has been associated with complications, including sciatic, femoral, and peroneal nerve palsies [11, 12, 13, 14]; low back pain [15, 16, 17, 18]; abnormal gait [19, 20], and dislocation [21].

It is well-known that preoperative pelvic radiographs are helpful in assessing LLD but also are subject to variation as a result of changes in the position of limbs and pelvis. Different measurement techniques are used to determine the LLD. As a pelvic reference, both ischial tuberosities and the teardrops are used. On the femoral side, the lesser trochanter is used. LLD is defined as the difference of the distance between a femoral and a pelvic landmark on both sides.

In the literature, two radiological techniques prevail and are commonly utilised in clinical practise. The distance between the most inferior point of Ischia and the lesser trochanter is measured using Williamson and Reckling's methods, whereas in method described by Woolson *et al.* distance between inferior point of acetabular tear drop and lesser trochanter is measured [22, 23].

**Table 1:** Different methods used to determine LLDs on an AP pelvic radiograph

Study Landmark	Pelvis		Femur	
	IT	BI	LT	CH
Austin <i>et al.</i> (2003) [24]		x	x	
Bono (2004) [25]	x		x	
Clark <i>et al.</i> (2006) [26]		x	x	
Eggl <i>et al.</i> (1998) [27]	x		x	
Gonzalez Della Valle <i>et al.</i> (2005) [28]	x		x	
Hoikka <i>et al.</i> (1991) [29]		x	x	
Khanduja <i>et al.</i> (2006) [30]	x		v	
Konyves and Bannister (2005) [31]	x		x	
Krishnan <i>et al.</i> (2006) [32]		x		x
Maloney and Keeney (2004) [33]		x	x	
Matsuda <i>et al.</i> (2006) [34]	x		x	
Mihalko <i>et al.</i> (2001) [35]	x		x	
Murphy and Ecker (2007) [36]	x		x	
Parvizi <i>et al.</i> (2003) [37]		x	x	
Ranawat and Rodriguez (1997) [38]	x		x	
Rand and Ilstrup (1983) [39]		x	x	
Sathappan <i>et al.</i> (2008) [40]	x		x	
Suh <i>et al.</i> (2004) [41]		x	x	
Unnanuntana <i>et al.</i> (2009) [42]	x		x	
Wedemeyer <i>et al.</i> (2008) [43]	x			x
White and Dougall (2002) [44]	x		x	
Williamson and Reckling (1978) [45]		x	x	
Woo and Morrey (1982) [46]	x	x	x	
Woolson <i>et al.</i> [47] (1999)	x		x	

IT = interteardrop line; BI = bischial line; LT = tip of the lesser trochanter; CH = center of the femoral head.

All methods for measuring LLD are subject to error. Error margins can be reduced by using standardised radiograph magnification, accurate and secure patient positioning to reduce pelvic tilt and rotation and taking care over the placement of computer cursors when measuring lengths.

This study was undertaken to establish the most appropriate method of measuring limb length discrepancy using pelvic radiographs out of two well known measurement techniques.

### Objectives

To assess the which radiographic measurement technique is most appropriate for measuring leg length from a digital pelvic x ray preoperatively and postoperatively and evaluated their reliability.

### Materials and Methods

#### Source

The study was done on preoperative and postoperative pelvic radiographs obtained from 40 patients who underwent total hip replacement painful arthritis of hip were operated in the

Orthopaedic Department of K R HOSPITAL, Mysuru during November 2019 to January 2022 fulfilling the inclusion criteria and exclusion criteria.

**Type of study:** Prospective study.

**Area of study** Department of Orthopaedics, K R Hospital Mysore Medical College & Research Institute, Mysore.

**Sample size:** 40

**Duration of study:** November 2019 to January 2022.

### Inclusion Criteria

1. Patients of age more than 20yrs and of either sex who had clinical feature of painful arthritis of hip.
2. X Ray of the patient's hip must show well established arthritic changes in the form of joint space reduction with or without subchondral cyst.

### Exclusion Criteria

1. Patients unwilling to consent for the study
2. Patients who are medically unfit for major surgery
3. Patients with clinically detectable focus of locally active infection
4. Ipsilateral knee pathology and degenerative condition of knee
5. No evidence for flexion contracture of hip or knee
6. No previous arthroplasty of hip
7. Deformity of the spine

### Methods of collection of data

After obtaining valid consent, the complete data was collected from the patients by taking history, detailed clinical examination was done to rule out ipsilateral knee deformity and to rule out contralateral hip involvement and relevant investigations like CRP and ESR was sent to rule out local infection of the hip. All cases with TOTAL HIP Replacement were evaluated for limb length using the proposed criteria. Following consent and surgery.

### Methodology

We evaluated all cases undergoing THR for arthritis. Leg length was calculated using digital x-rays by 2 examiners orthopedic surgeon and radiologist (who were blinded) preoperatively and postoperatively. While taking the X-ray, in order to avoid inaccuracies in measuring discrepancy, all the patients were in a standard position (anatomical position), internally rotating the lower limb when necessary and looking for maximum symmetry of the limb posture.

Each examiner measures 80 measurement each for 40 THR cases, considering the two different methods of measuring limb length on pelvic AP radiographs, Radiographs were exchanged via DICOM file.

Leg length was measured by drawing 3 lines at 3 levels (Inter teardrop line, Interischial line, line drawn on most medial point on lesser trochanter)

**First method:** On digital X-ray a line was drawn at the level of & parallel to inter teardrop area and intersecting the most prominent medial part of lesser trochanter on each side (TD-LT).

**Second method:** line was drawn at most inferior point of ischial tuberosity to inter teardrop area and line drawn at most prominent medial part of lesser trochanter on each side (IT-

LT) When performing the X-ray, in order to avoid inaccuracies in measurements of limb length, all the patients were in a standard position (anatomical position), internally rotating both the lower limb when necessary and looking for maximum symmetry of the limb posture and the measurements were taken preoperatively and postoperatively.

**Analysis of data**

We evaluated 40 cases undergoing THR for painful arthritis of hip at K R Hospital MMCRI for interobserver reliability of limb length measurements using 2 different methods on digital pelvic x-rays by 2 different examiners. IBM SSPS software version 23 is used to analyse statistical data.

Pictures depicting x-rays, where measurements were taken on a digital x-ray using a computer software.



**Fig 1:** X-ray Shows Measuring Limb Length between Inter teardrop Line And Lesser Trochanter



**Fig 2:** X-ray Shows Measuring Limb Length between Interischial Line and Lesser Trochanter

**Results**

For measuring limb length using teardrop as a pelvic reference and lesser trochanter as femoral reference inter-observer agreement for radiological measurements kappa=0.893 (good agreement) for pre-operative radiographic measurements and kappa=0.813 (good agreement) for post-operative radiographic measurements. By using ischial tuberosity as a pelvic reference and lesser trochanter as femoral reference inter-observer agreement for radiological measurements kappa=0.723 (Substantial agreement) for pre-operative radiographic measurements and kappa=0.752 (Substantial agreement) for post-operative radiographic measurements.

**Table 1:** Interpretation of Cohens Kappa for statistical strength of agreement.

Kappa	Level of agreement	% of data reliability
0 - 0.20	None	0-4%
0.21 - 0.39	Minimal	4-15%
0.40 - 0.59	Weak	15-35%
0.60 - 0.79	Moderate	35-63%
0.80 - 0.90	Strong	64-81%
Above 0.90	Almost Perfect	82-100%

**Discussion**

Two radiological techniques predominate in the literature and are widely used in clinical practice. In the methods described by Williamson and Reckling distance between most inferior point of Ischia and lesser trochanter is measured, whereas in method described by Woolson *et al.* distance between inferior point of acetabular tear drop and lesser trochanter is measured<sup>22,23</sup>. Neither Woolson’s nor Williamson’s method takes account of hip flexion or abduction deformity at the time of the x-ray (which tends to reduce the measured LLD) or any causes of LLD which does not involves the hip<sup>[23]</sup>.

Radiographic measurement has been found to be more accurate compared to clinical measurement<sup>[48-51]</sup>. Leitzes *et al.* used the electronic calliper measurement as a gold standard in their study<sup>[52]</sup>. In this study, we compared the plain radiographic measurement methods and reliability.

There are many described methods of measuring LLD, all of which have their advantages and disadvantages. Clinical measurement between two bony prominences and block measurement to clinically level the pelvis are examples of simple techniques. Studies have shown that block measurement is more accurate than tape measurement of true and apparent leg length<sup>[53, 54]</sup>. Terry *et al.*<sup>[53]</sup> have shown that radiographic measurement is more accurate than clinical measurement in determining leg length discrepancy, however, this does involve exposure to radiation. There is much debate as to whether CT scanograms or full leg length radiographs are more reliable. Scanograms with radio-opaque rulers give more accurate LLD measurement but can miss angular deformities of the femur or tibia and fixed flexion deformities<sup>[55]</sup>. Long leg radiographs can be done in a number of ways (orthoroentgenograms, teleoroetgenograms,) depending on the equipment and skills available<sup>[56]</sup>. CT scanograms are comparable with radiographs but the dose of radiation received by the patient may be less if adequate images are gained on the first scan<sup>[57]</sup>.

CT Scanogram and MRI has very high intraobserver and interobserver reliability in various studies. Both modalities are not available in tertiary centres and bear a financial burden to the patients. Hence pelvic radiograph was chosen as the method in our study.

Two radiological techniques predominate in the literature and are widely used in clinical practice. In the methods described by Williamson and Reckling distance between most inferior point of Ischia and lesser trochanter is measured, whereas in method described by Woolson *et al.* distance between inferior point of acetabular tear drop and lesser trochanter is measured<sup>[58, 59]</sup>. Neither Woolson’s nor Williamson’s method takes account of hip flexion or abduction deformity at the time of the x-ray (which tends to reduce the measured LLD) or any causes of LLD which does not involves the hip<sup>[58]</sup>.

Meermans *et al.* evaluated LLD measurement preoperatively when templating for THA. The authors found that LLD measurement by using the interteardrop line correlated with LLD measurement by full-leg radiographs better than using the bi-ischial line. The teardrop points have been found to be reliable and constant landmarks of the pelvis<sup>[60]</sup>, due to the vertical and rotational stability of these points in association with different pelvis positions.

Heaver *et al.* reported that inter ischial line was best pelvic landmark for measurement of LLD, whereas Meermans *et al.* reported teardrop line to be better<sup>[60]</sup>. Meermans *et al.* went on to say that the femoral reference point should be the centre of the femoral head rather than the lesser trochanter.

Tipton *et al.* reported that LLD estimated on AP radiograph of

the pelvis are not comparable to LLD calculated on full length radiographs of limb and hence taking only pelvic radiograph to assess LLD is not adequate. Tipton *et al.* reported that LLD calculated on AP radiograph of the pelvis are not comparable to LLD calculated on full length radiographs of limb and hence taking only pelvic radiograph to assess LLD is not adequate<sup>61</sup>. He reports an intraobserver agreement, when the interteardrop line was used produced values of 0.66 for tear drop to LT and 0.62 for tear drop to centre of femoral head. The interobserver agreement was strong for the bi-ischial line, 0.69 and 0.78 for bi-ischial to LT and bi-ischial to centre of femoral head, respectively<sup>61</sup>.

Keršič *et al.* in their study of 119 primary THA patients reported a LLD of 5-8 mm between preoperative clinical and radiological LLD but, this difference decreased to 1-2 mm postoperatively<sup>62</sup>. Sayednoor *et al.* also supported these findings in their study<sup>63</sup>.

In a study by Martin Kjellberg *et al.*<sup>64</sup>, computed tomographic scanogram (CT-Scan) was used to evaluate its accuracy by comparing it with LLD measurement on radiograph. They found excellent interobserver reliability (mean ICC 0.83) and intraobserver reproducibility (ICC 0.90 and 0.88) of the LLD measurements on plain radiographs. There was a moderate to excellent agreement, but with wide variation of measurements among the four observers, when plain radiographic measurement was compared with CT-scanogram (ICC 0.58, 0.60, 0.71, and 0.82).

There is no universal agreement for taking reference points to accurately measure limb lengths. Various authors have pointed out that the measurements from plain radiographs are susceptible to error, due to variations in positioning of the pelvis relative to the plane of the film and the divergence of the X-ray beams.

The abduction/adduction deformities of the femur with respect to the pelvis also cause substantial error in the measurement of the length and offset changes. A radiograph cannot detect angular deformities of the lower limb and may

underestimate the LLD in patients with discrepancies in foot height<sup>65, 66</sup>. These points should be improved in order to achieve more accurate measurements.

The rotation of the lesser trochanter and the position of the tip can vary according to the rotation of the leg when taking the radiographs. In order to minimize this variation, the legs were kept with a symmetrical internal rotation by the same radiology assistant to make measurements as standardized as possible. The radiographs were accepted for inclusion when obturator foramen, lesser trochanter, and knee and ankle joint all appeared symmetrical bilaterally.

This study is limited in that the leg length discrepancy is only measured across the hip joint. This does not account for any discrepancy arising from the femoral shaft, knee, tibia or ankle and subsequent imaging must be directed by thorough history taking and clinical examination., limb length was evaluated based on the plain pelvic radiographs instead of the CT scans, which have been used in other studies to eliminate the variables of pelvic tilt that exists while taking radiographs<sup>68, 69</sup>. Measurements and calculations from plain X-rays are susceptible to error, due to variations in positioning of the pelvis relative to the plane of the film and the divergence of the X-ray beams<sup>67</sup>. Our study comprises of small study group.

### Conclusion


In our study, Measurement of limb length on radiographs has excellent interobserver reliability with the use of the inter teardrop as a pelvic landmark was a better with measurements to the lesser trochanter. Interobserver variability testing showed less agreement when the ischial tuberosity was used as a pelvic landmark compared with the teardrop. The accuracy of this method is limited when compared with CT-scanogram.

Clinicians should be aware of this limitation when using the radiographic method in their clinical practice

### Master Chart

S. No	AGE (years)	SEX	Diagnosis	SIDE	Tear Drop-LT				Ischial Tuberosity -LT			
					Examinor-1(TD-LT)		Examinor-2(TD-LT)		Examinor-1(IT-LT)		Examinor-2(IT-LT)	
					Pre-Op	Post-op	Pre-Op	Post-op	Pre-Op	Post-op	Pre-Op	Post-op
1	32	M	AVN	R	4.2	5.2	4.2	5.2	-0.9	-0.1	-0.9	-0.1
2	51	M	OA	R	3.2	4.6	3.2	4.5	-0.7	0.2	-0.6	0.2
3	28	F	AVN	L	3.9	4.2	3.9	4.2	-1.1	-0.2	-1	-0.2
4	56	M	OA	R	3.8	5	3.8	5	-0.8	-0.1	-0.7	-0.1
5	27	F	AVN	L	3.3	4.5	3.3	4.5	-0.9	-0.3	-0.9	-0.3
6	56	M	OA	R	4.5	4.9	4.5	4.8	-0.8	0.1	-0.8	0.1
7	62	M	OA	L	3.6	4.2	3.6	4.2	-1.3	0.3	-1.2	0.4
8	59	F	OA	L	4.1	4.6	4.1	4.6	-1	-0.2	-1	-0.2
9	61	M	OA	R	5	7	5.1	7	-1.5	-0.5	-1.5	-0.5
10	35	M	AVN	L	3.9	4.2	3.9	4.1	-0.3	0.7	-0.3	0.7
11	52	M	OA	R	3.8	5	3.8	5	-0.9	0.2	-0.9	0.3
12	49	F	OA	R	4.3	5.4	4.3	5.4	-0.6	-0.1	-0.6	-0.1
13	61	M	OA	L	2.4	3.5	2.4	3.5	-1.2	-0.2	-1.2	-0.2
14	26	M	AVN	R	3.7	3.9	3.8	3.9	-1.3	-0.5	-1.3	-0.5
15	36	F	AVN	L	3.1	4.1	3.1	4	-0.2	0.4	-0.2	0.4
16	39	M	OA	R	2.9	4.4	2.9	4.4	-0.7	0.5	-0.7	0.6
17	45	M	OA	L	3.7	4.3	3.7	4.4	-0.8	-0.1	-0.8	-0.1
18	41	F	OA	L	3.2	3.4	3.2	3.4	-0.2	0.6	-0.2	0.6
19	32	M	OA	R	4	6	4	6	-0.8	0.3	-0.9	0.4
20	31	F	AVN	L	1.8	3.1	1.8	3.1	-0.9	0.2	-0.9	0.3
21	52	M	OA	R	4.2	3.9	4.2	3.9	-0.6	0.4	-0.6	0.4
22	33	M	AVN	L	5.2	6.1	5.2	6.2	-0.9	0.2	-0.9	0.2
23	28	M	AVN	R	3.8	4.2	3.8	4.2	-1.7	-0.8	-1.8	-0.9
24	32	M	AVN	L	3.3	3.6	3.3	3.6	-1.1	-0.1	-1	-0.1

25	69	M	OA	R	4.2	4.4	4.2	4.4	-0.7	0.3	-0.7	0.3
26	52	M	OA	L	2.9	3.2	2.9	3.2	-0.8	0.4	-0.8	0.4
27	70	M	OA	R	4.5	4.1	4.5	4.1	-0.9	0.5	-0.9	0.5
28	65	F	OA	L	5.1	5.2	5.1	5.2	-0.2	0.8	-0.3	0.8
29	61	M	OA	R	5.4	5.2	5.4	5.2	-1.3	0.2	-1.3	0.2
30	54	M	OA	L	3.5	4.6	3.5	4.5	-1	-0.2	-1	-0.2
31	52	M	TB	L	3.9	3.7	3.9	3.7	-0.6	0.2	-0.6	0.2
32	57	M	OA	R	4.1	4.3	4.1	4.3	-0.8	0.5	-0.8	0.5
33	62	F	AVN	R	3.9	4.2	3.9	4.2	-1.2	-0.2	-1.3	-0.2
34	60	M	OA	R	5	7	5	7	-1.8	-0.6	-1.8	-0.7
35	69	F	OA	L	2.8	4.2	2.8	4.2	-0.6	0.8	-0.6	0.8
36	55	M	OA	R	2.9	4.4	2.9	4.4	-0.4	0.7	-0.4	0.7
37	62	F	OA	R	3.7	4.5	3.8	4.5	-0.3	0.6	-0.3	0.6
38	52	F	OA	L	3.8	3.2	3.9	3.2	-0.7	-0.2	-0.7	-0.2
39	59	F	AVN	R	4.3	5.2	4.3	5.2	-0.6	0.7	-0.7	0.6
40	62	M	AVN	L	3.9	3.7	3.9	3.7	-0.9	-0.1	-0.9	-0.2



**Institutional Ethics Committee** Tel : 0821 - 2428774  
Mysore Medical College & Research Institute  
and Associated Hospitals MYSORE-570021  
EC REG.ECR/134/Inst/KAJ/2013/RR-16 e-mail : ethicscom.mmcri@gmail.com

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Ref : \_\_\_\_\_ Date : 25<sup>th</sup> November 2019

To,  
Dr. Mohan Kumar  
1<sup>st</sup> Year Post Graduate,  
Department of Orthopedics,  
Mysore Medical College & Research Institute, Mysore- 570001.

Ref: Dissertation Synopsis Study: "Clinical and radiological outcomes of total hip replacement - clinical study".

Sub: Institutional Ethics Committee (IEC) approval for the conduct of the above mentioned Institutional/ dissertation synopsis under Rajiv Gandhi University of Health Sciences, Bengaluru.

The synopsis was reviewed in detail by Ethics Committee about the ethical issues involved and was approved with the following conditions.

Remarks/ Suggestions:

- The IEC hereby approves the research proposal to be conducted in it's presented from only and expects to be informed immediately (Within 24 hours) in case of any Serious Adverse Events (SAEs)
- The IEC expects to be informed about the progress of the study at six (06) months once from date of its first approval letter and case by case basis for pharmacodynamic study, pharmacokinetic study, etc.
- IEC will have right to monitor study site and conduct of study with prior intimation.
- This approval is solely for the ethical issues involved in the study. IEC is not responsible for the technical and scientific contents involved in the study. Respective guides and HODs are responsible for the scientific conduct of the study.
- Investigator and respective guides are hereby informed to stick to the standard protocol, ethical issues and practices. Due permission from the Head of Department concerned should be taken before commencing any activity in relation to the study. Informed consent should be taken from subjects involved for all the prospective studies and in case of retrospective studies; permission should be taken from the Head of Institution to access subjects' case sheets and records.

Approval Authority : Member Secretary

Signature & Date : \_\_\_\_\_ 25/11/19

Seal : \_\_\_\_\_

**Member Secretary**  
**Institutional Ethics Committee**  
**Mysore Medical College and Research**  
**Institute and Associated Hospitals**  
**MYSORE-570 021**  
**EC REG.ECR/134/Inst/KAJ/2013/RR-16**

Ethics Committee Approval Letter 2019

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