"PRE AND POST OPERATIVE GAIT ANALYSIS IN PATIENTS UNDERGOING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING PATELLAR TENDON BONE GRAFT– A ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY"

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ABBREVIATIONS

ACL	:	Anterior cruciate ligament
PTBG	:	Patellar tendon bone graft
OA	:	Osteoarthritis
LyE	:	Lyapunov exponent
+/-	:	Plus/minus
%	:	Percentage
IA	:	Intraarticular
CM	:	Centimetre
RTA	:	Road Traffic Accident
HTN	:	Hypertension
HS	:	Highly Significant
VS	:	Very Significant
< / >	:	Lesser than / Greater than
Sq.cm	:	Square Centimetre
Vs	:	Versus
NA	:	Not Applicable
TLC	:	Total Leukocyte Count
DLC	:	Differential Leukocyte Count
ESR	:	Erythrocyte Sedimentation Rate
FBS	:	Fasting Blood Sugar
RBS	:	Random Blood Sugar
HBsAg	:	Hepatitis B Surface Antigen
ECG	:	Electrocardiography
MmHg	:	Millimeters of mercury
HIV	:	Human Immunodeficiency Virus
DSP	:	Double support phase
CGM	:	Conventional gait model
IK	:	Inverse kinetics
DK	:	Direct kinetics
AKA	:	Also known as
IKDC	:	International knee documentation committee
GRF	:	Ground reaction force

BMI	:	Body mass index
GEDEM	:	Gait evaluation differential entropy method
ODI	:	Oswestry disability index
FERA	:	Flexion extension rotation angle
VERA	:	Varus eversion rotation angle
IERA	:	Internal and external rotation angle
FDHO	:	Force driven harmonic oscillator
PSF	:	Preferred stride frequency
RLL	:	Right lower limb
LLL	:	Left lower limb
Gm/dl	:	Grams per deciliter
DM-2	:	Diabetes mellitus
I.P NO	:	In patient number
ROM	:	Range of motion
Sec	:	Seconds
M/S	:	Meters per second
%height/s	:	Percentage height per second
Steps/min	:	Steps per minute
DEG	:	Degree

ABSTRACT

TITLE: "PRE AND POST OPERATIVE GAIT ANALYSIS IN PATIENTS UNDERGOING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING PATELLAR TENDON BONE GRAFT - A ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY."

INTRODUCTION:

- Gait defines as the locomotion achieved by movement of human limbs. In humans it is achieved by bi-pedal and bi-phasic forward propulsion which has meandrous movements with least possible expense of energy.
- Gait has three components :

1. Progression
2. Stability
3. Energy conservation
    1. PROGRESSION: The primary force created by lower limb to attain forward fall of body weight while maintaining secondary momentum generated by upper limb through swinging motion.
    2. STABILITY: The forward fall is then controlled throughout the phase of the gait while maintaining in upright position. During the stance phase the body is most stable where the ankle, hip and knee are vertically aligned, the stability is maintained by strong ligaments of the hip and knee. The balance between the knee stability and shock absorption is maintained by contraction of quadriceps.
    3. ENERGY CONSERVATION: It is calculated by oxygen consumed per meter travelled. Human gait enhances this by reducing the quantity of

muscular effort which is required for walking. This is achieved by co-ordinated pelvic, knee and ankle motion.

- The ligaments of hip and knee play a vibrant role in gait, any injury to these ligaments will alter the pattern of the gait.
- Anterior cruciate ligament is commonly injured and associated with instability of knee which results in alteration in normal pattern of the gait.
- As arthroscopic surgeries for ACL ligament injury emerged in the late 1990's. The analysis regarding gait pattern post reconstruction of ACL has been given a faint importance.
- The instability of post ACL injury is due to change in biomechanics of knee as tibia overrides the femur anteriorly while reclining downstairs or walking on uneven surfaces.
- After introducing 3D-locomotory gait analyser, there has been a profound use of this system to analyse the discrepancy in the pattern of gait in ACL injury as well as post ACL reconstruction.
- The emergence of this system has been a helpful boon for the patients who have undergone ACL reconstructive surgery to revert to their normal gait pattern.
- The graft selection for ACL reconstruction has numerous options which comprises of bone patellar tendon bone graft, hamstring graft, allografts and synthetic grafts.
- Among these bone-patellar tendon-bone graft (BPTB) has high tensile strength and quicker healing capabilities. Though it has post-operative donor site morbidity, the merits for reconstruction of ACL with BPTB graft is comparatively better to its demerits.

AIMS AND OBJECTIVES:

The objective of this study is to determine the Clinical outcome by analyzing gait using BTS SMART GAIT ANALYSER FOLLOWING SIMPLE HELEN HAYES PROTOCOL in patients of anterior cruciate ligament tear reconstruction with patellar tendon bone graft.

MATERIALS AND METHODS:

Study Design: A one year hospital based observational study. Patients will undergo anterior cruciate ligament tear reconstruction with patellar tendon bone graft under spinal anesthesia or general anesthesia. Post-operative physiotherapy will be followed according to protocol, to evaluate the clinical outcome follow up gait analysis of the patient will be done after 9months of ACL reconstruction.

Methodology:

Method:

Lower limb motion will be tracked using a motion capture system (BTS SMART GAIT ANALYSER) with one position sensor (INFINI-T) equipped with embedded infrared cameras (SMART-DX 6000 AND VIXTA CAMERAS). The system will track position and orientation of clusters of active markers. In Simple Helen Hayes protocol [5][6] there are 6 phases:-

1) Subject preparation: Anthropometric measurements like ASIS breadth, pelvic depth, leg length, knee diameter, malleolus width, height and weight are marked and markers are attached on different parts of body .In Simple Helen Hayes 15 markers are attached, in which 3 are on pelvis, 2 are on thigh, 2 are on each shank, and 2 are on each foot, this version is used just to evaluate lower limb and pelvis behavior

2) Acquisition phase: a) standing taskb) Walking task

3) Elaboration phase: a) Tracking

b) Calculation protocol selection

c) Events

4) Reporting phase:a) Mean spatio-temporal parameters

b) Gait profile score

c) Gait variable score

d) Gait deviation index

5) Checking marker location

6) Helen Hayes With Medial Markers (optional).

After doing gait analysis main parameters to see are:

a) Knee Valgus Varus in degrees

b) Knee flexion-extension in degrees

c) Knee rotation in degrees

d) Ankle dorsal-plantar flexion in degrees

e) All temporal parameters

1. Stride time (sec)
2. Stance time (sec)
3. Swing time (sec)
4. Stance phase (%)
5. Swing phase (%)
6. Single support phase (%)
7. Double support phase (%)
8. Mean velocity (m/s)
9. Mean velocity (%height)
10. Cadence (steps/min)

The patients who are undergoing anterior cruciate ligament tear reconstruction with patellar tendon bone graft in KLE'S Dr.PrabhakarKore Hospital & Research Centre and Charitable Hospital, Belagavi, will be examined thoroughly and necessary investigations will be done. Then the patients who are being assessed will be explained in detail about the study and informed written consent will be taken. The

patient will have to be operated as per fitness for the surgery. Patients are treated with Anterior Cruciate ligament tear reconstruction using patellar tendon bone graft and gait analyser used for the study is BTS SMART GAIT ANALYSER BY FOLLOWING SIMPLE HELEN HAYES PROTOCOL.

POST OPERATIVE PHYSIOTHERAPY:-

Patients are subjected to physiotherapy for 9 months which is "Accelerated Rehabilitation after Anterior Cruciate Ligament Reconstruction with Patellar Tendon bone graft –MODIFIED WILK'S PROTOCOL."

Post-operative gait analysis is done after 9months of extensive physiotherapy protocol and the parameters are compared with preoperative gait analysis.

RESULTS:

- Based on statistical analysis consolidated percentage of all the gait parameters traced by gait analysis using BTS SMART GAIT ANALYSER following Simple Helen Hayes protocol in pre and post-operative patients, excellent improvement of knee valgus-varus and swing time was seen in 100%(15) of the post-operative patients. In contrast, other parameters with excellent improvement in post-operativepatients are knee rotation in 20% of the patients, knee flexion-extension in 80% of the patients, stance time in 13.33% of the patients, stance phase in 20% of the patients, swing phase in 73.33% of the patients, single support phase in 13.33% of the patients, double support phase in 6.67% of the patients and finally mean velocity (m/s) in 6.67% of the patients.
- Gait parameters which are improved than pre-operative data are knee rotation in 80% of the patients, knee flexion-extension in 20% of the patients, ankle dorsal-plantar flexion and stride time in 100% of the patients, stance time in

86.67% of the patients, stance phase in 80% of the patients, swing phase in 26.67% of the patients, single support phase in 66.67% of the patients, double support phase in 86.67% of the patients, mean velocity (m/s) in 93.33% of the patients, mean velocity (%height/s) in 73.33% of the patients and cadence in 80% of the patients.

- Some parameters which are not improved even after following proper physiotherapy protocols are single support phase in 20% of the patients, double support phase in 6.67% of the patients, mean velocity (%height/s) in 26.67% of the patients and cadence in 20% of the patients.

CONCLUSION:

- Gait parameters which are traced by BTS SMART GAIT ANALYSER following SIMPLE HELEN HAYES PROTOCOL.Pre-operative gait analysis is done in ACL tear patients and in same patients post-operative gait analysis is done after 9 months of follow up. Based on our study we can easily state that gait analysis data generated using this system is one of the sophisticated way to know the technical efficacy of the surgery, diagnostic thinking, treatment and outcome efficacy and there are many types of grafts but BPTB graft is very helpful in normalizing many parameters of gait, returning to daily activities/sports activities with significantly less requirement of revision surgery and less donor site comorbidity.

KEYWORDS: Anterior cruciate ligament reconstruction, Simple Helen Hayes Protocol, gait analysis, patellar tendon bone graft, motion captures system, BTS SMART GAIT ANALYSER.

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INTRODUCTION

- Gait defines as the locomotion achieved by movement of human limbs. In humans it is achieved by bi-pedal and bi-phasic forward propulsion which has meandrous movements with least possible expense of energy.[1]

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morbidity, the merits for reconstruction of ACL with BPTB graft is comparatively better to its demerits.

- Human and animal walking manner was first observed and recorded by the great philosopher and researcher Aristotle (384-322BC).[2, 3]

- Zigzag line pattern was observed by Aristotle when he tried to explain about walking pattern using long reed's tip immersed in ink and clipped to head of a walking person.[3]

- Various gait patterns are seen and specific name is given for each based on the complexity of biological system which interacts with environment, makes these unique patterns.
- The treatment purpose is minimally invasive anterior cruciate ligament repair which results in the anatomic reconstruction of the articular area, axis, rotation and connection re-establishment for the femur and tibia with patellar tendon-bone graft bridging the commination and with early functional rehabilitation. Promising results are obtained by patellar tendon-bone graft due to fast healing by bone to bone, vascularisation protection, reduced complication rate, reduced primary or secondary grafting requirements, and shortening of the operative time and also increases resilience to mechanical stress. It is a challenging technique, requiring a vigilant intraoperative clinical and fluoroscopic control to re-establish limb axis, rotation.
- The electrical impulse generated by the muscles involved in the gait is used to establish the protocol to offer doctors with quantitative and objective data needed to analyse any possible gait dysfunction. The works of M. Kadaba inspired this protocol implementation by R. Davis, respectively developed at

the Helen Hayes Hospital, and the Newington Hospital (Kadaba et al. 1989-90: Davis et al, 1991) and this protocol necessitates the use of BTS SMART-DX system with a minimum of 6 video cameras for the kinematic analysis. For the kinetic analysis, at least one BTS P-6000 force platform is needed. The assessment of the muscular activity necessitates the use of BTS FREE EMG surface electromyogram. Gait analysis efficacy was summarised by the modern authentication base for clinical effectiveness.

- Systemic review of gait analysis from 2000 Jan to Sep 2009, assessed using a hierarchical model to gain information regarding gait analysis.
- Among 1528 references that were acknowledged, 116 original articles were addressed for technical gait analysis accuracy, 89 were identified for diagnostic accuracy, and 11 were identified for thinking and treatment efficacy.
- A dynamic difference is distinguished in angle of tibial rotation which is present in ACL tear. The patient with ACL tear has rotation of tibia further internally in the mid-stance phase. There is no prominent difference that can be identified in adduction-abduction angles and antero-posterior translation. A greater flexion gait strategy along with excessive tibial internal rotation during walking results in rapid cartilage thinning throughout the knee. The pre-operative data during this examination will be useful to comprehend post ACL reconstruction.
- The high quality of graft in ACL reconstruction is a central issue—patellar tendon-bone graft was commonly used graft for torn ACL reconstruction.

OBJECTIVES

The objective of this study is to determine the Clinical outcome by analyzing gait using BTS SMART GAIT ANALYSER FOLLOWING SIMPLE HELEN HAYES PROTOCOL in patients of anterior cruciate ligament tear reconstruction with patellar tendon bone graft.

REVIEW OF LITERATURE

GAIT HISTORY:

- Human and animal walking manner was first commented and recorded by the great philosopher and researcher Aristotle (384-322BC).[2, 3]
- Girolamo Cardan (1501–1576) studied the properties of three- dimensional angles of human gait.[3]
- Francoise Margendie (1783-1855) proposed physiology of walking, whereas anatomy, mechanics of walking, alignment of lower limb and trunk during gait cycle was proposed by Wilhelm Eduard Weber (1804-1891), Eduard Friedrich Weber (1806-1871).[4]
- Guillaume Duchenne (1806–1875) corrected the Willhelm Eduard Weber (1804-1891) and Eduard Friedrich Weber (1806-1871) theory of passive swing phase of lower limb due to gravity, and proposed the hip flexor activity while walking and pattern of gait where pelvic elevated.
- Gaston Carlet (1849–1892) proposed double bump of force generated by the ground reaction, by placing three pressure transducers in the shoe and recorded the ground reaction force employed by foot during different phases of the gait cycle.[3]
- Otto Fischer and Willhelm Braune measured the inertial variabilities of human walking pattern and Otto Fischer was first to conduct 3-dimensional gait analysis using Geislers tubes.[3, 6]
- Georges Demeny (1850-1918) and Edward Muybridge (1830-1904) pioneered the photographic method and photography of human movement respectively.[7, 8]

- Nikolai Bernstein (1896-1966), Jules Amar (1879 -1935) and Wallace Fenn (1893-1971) developed different types of component force plates to know the pattern of force generated in different sub-phases of gait cycle.[12]
- Gait cycle and pioneering of electromyography study was done by Jacquelin Perry (1918). [9.10,11]

TASKS OF GAIT: [13, 14]

- Body balance and posture maintenance.
- Gentle heel and toe landing by controlling the foot trajectory for safe ground clearance.
- In normal gait, to preserve the current forward motion and to upsurge the forward velocity, mechanical energy is generated.
- Mechanical energy is absorbed for stability, shock absorption and to downsurge the forward velocity of the body.

GAIT INITIATION:

- Gait initiation begins with activation of two muscles which are vastus lateralis and tibialis anterior, in combination with de-activation of gastrocnemius muscle.[15]
- Abduction of hip in swing limb occurs instantaneously at the time of contraction of vastus lateralis and tibialis anterior of stance limb.[15]
- Initiation phase=0.64s. [15, 16]

PHASES OF GAIT CYCLE {STRIDE}:

A. **Stance phase** {60%}: At that particular moment when one extremity contacts the ground and continue to some part of the foot which is in connection with the ground.
B. **Swing phase** {40%}: During which the foot doesn't come in contact with the walking surface whereas the other leg and foot bear the body weight.

DOUBLE SUPPORT PHASE (DSP) :[20, 21]

- Leading Lower limb of one side of the body is beginning its stance phase & the opposite side is ending its stance phase.[20]
- Both the limbs are on the ground at the same time, during double support.
- In running DSP is absent.[22]

STRIDE LENGTH: [23]

It is the linear distance covered by successive ground contact of the same foot

EVENTS OF PHASES: [19, 20, 21, 22, 25]

Stance phase:-

1) Heel strike
2) Foot flat
3) Mid-stance
4) Heel off
5) Toe off

Swing phase:-

1) Acceleration

2) Mid-swing

3) Deceleration

STANCE PHASE: [19, 20, 21, 22, 25]

1. **HEEL STRIKE:** When the heel strikes the ground while walking

2. **FOOT FLAT:** The foot is flat on the walking surface.

3. **MID STANCE:** Instant at which the bodyweight is directly over the supporting lower extremity.

4. **HEEL OFF**: The instant following midstance at which the heel of the reference extremity leaves the ground.

5**. TOE OFF**: The instant following the heel off where only the toe of the reference extremity leaves the ground.

HIP IN STANCE PHASE:

Heel strike to foot flat: - Normal 30-degree flexion at hip joint and muscles helpful for this phase are Erector spinae, gluteus maximus, and hamstrings.[25]

Foot flat to Midstance: - 30-degree flexion to neutral and muscles helpful for this phase are Gluteus maximus at the commencement to oppose flexion movement, then activity ceases as moment changes from flexion to extension.

Midstance to heel off: - Hip will be in extension, no particular muscle involved for a specific stage, conversion of muscle takes place.

Heel off to toe-off: - 10-degree hyperextension to neutral and muscles helpful in this stage are Iliopsoas, adductor magnus, adductor longus muscles. [25, 26, 27]

KNEE IN STANCE PHASE:

Heel strike to flat foot: - Knee joint will change from 0 degrees to 15-degree flexion and muscles helpful in this stage are quadriceps. [27]

Foot flat to Midstance: - Knee joint will change from 15-degree flexion to 5-degree extension and muscles helpful in this stage are quadriceps which contract in the early part and then no activity is required. [25, 26, 27]

Midstance to heel off: - Knee joint will change from 5-degree flexion to neutral because of the stance phase of other limb and no muscle activity is required in the phase of sound limb. [29]

Heel off to toe-off: - In this stage, the knee joint will change from neutral .i.e., from neutral to 40-degree flexion and quadriceps muscle will help in controlling knee flexion. [29]

ANKLE & FOOT IN STANCE PHASE: [9, 10, 18, 30]

Heel strike to foot flat: - Ankle joint changes from 0 degree to 15 degrees plantar flexion which is done by eccentric action of tibialis anterior muscle which opposes plantar flexion movement.

Foot flat to Midstance: - Ankle joint changes from 15 degrees plantar flexion to 10-degree dorsiflexion because of Gastrocnemius & Soleus eccentrical action to oppose dorsiflexion movement & control tibial advancement.

Midstance to heel off: - In Midstance to heel off, change of 10-degrees dorsiflexion to 15-degrees dorsiflexion with the same muscle action as above.

Heel off to toe-off: – Changes from 15 degrees dorsiflexion to 20 degrees plantar flexion of the foot. [9, 10, 18, 30]

SWING PHASE:

Pre-swing or initial swing:- Starts once the toe leaves the walking surface. [9, 10, 18]

Mid stance:- It occurs approximately when the extremity passes directly beneath the body or while minimizing the acceleration to begin deceleration. [10, 19, 20, 21, 22, 25]

DECELERATION:- Just before the heel strike. [1, 10, 19]

HIP IN SWING PHASE: [9, 10, 19]

Acceleration to mid-swing: - It comes to 20-30 degree flexion, and muscles helping for hip flexor activity to initiate swing phase are Iliopsoas, rectus femoris, gracilis, Sartorius and tensor fascia lata.

Mid swing to deceleration: - 30-degree flexion to neutral happens with the activity of hamstrings muscle.

KNEE IN SWING PHASE:

Acceleration to mid-swing: - It is the activity of 40 degrees to 60-degree flexion using quadriceps, biceps femoris (short head), gracilis, Sartorius which contract concentrically.

Mid swing: - In this stage, there is a change in the angle of the knee from 60-degree flexion to 30-degree flexion because of the activity of the muscles same as above.

Deceleration: -Quadriceps contract concentrically to stabilise the knee in extension, in preparation for heel strike which leads to change in knee angle from 30-degree flexion to zero degrees extension.

ANKLE & FOOT IN SWING PHASE:

Acceleration to Mid swing: - Dorsi-flexors contracts to keep the toe off the ground.

Mid swing to deceleration: - Maintains the ankle in neutral till the heel strikes.

Two essential quantitative parameters of human gait are:

- Temporal parameters.
- Distance parameter.

TEMPORAL PARAMETERS:

Stance time: - Total time taken for stance phase of one extremity.

Single-limb support time: - Only one limb is on the walking surface in the gait cycle and the proportion of time that spent during the period is single-limb support time.

Double-limb support time: -Time span till both the feet are on the surface. In older adults and people with joint/ balance disorders, the percentage of time spent will be increased.

In speed walking, percentage of double-limb support time decreases.

Whereas while running there is always flight phase but no double support phase.

Swing time:- It is the amount of time that passes during the swing phase of one extremity in a gait cycle.

Stride time: - Time taken for 1 gait cycle.

Step length and time: - It is the straight length from the heel strike of leading extremity to the next heel strike of non-leading extremity. It refers to the time spent during a single step. Usually, measurement is expressed as sec/step.

Cadence: - Number of steps had taken in a minute or sec.

The cadence of man and women are 110 steps/min and 116 steps/min respectively.

Speed of gait or Walking velocity: [31]

In a specific direction, rate of linear forward motion of the body is called as walking velocity

Saunders determinants or Standing angles: [28]

A. Pelvic Obliquity
B. Pelvic Tilt
C. Pelvic Rotation
D. Hip Abduction-Adduction

E. Hip Flexion- Extension

F. Hip Rotation

G. Knee Valgus-Varus

H. Knee Flexion-Extension

I. Knee Rotation

J. Ankle dorsiflexion and plantar flexion

K. Foot progression.

But only four standing angles discussed in this study, they are

1. Knee Valgus-Varus (deg)
2. Knee Flexion-Extension (deg)
3. Knee rotation (deg)
4. Ankle dorsiflexion and plantar flexion (deg)

KNEE FLEXION-EXTENSION (DEG):

The sagittal motion measured at the intersection of the thigh and shank segments.

KNEE VALGUS- VARUS (DEG):

In gait analysis, medial or lateral deviation from the normal position due to existing pathology is measured.

KNEE ROTATION IN DEGREE

In vertical axis, knee rotation is permitted in the lower medial compartment. It is the rotation of the tibia in combination with different ligaments at a time for flexion to an extension or vice-versa.

ANKLE DORSAL-PLANTAR FLEXION IN DEGREES:

Angular deviation of the ankle joint during the whole cycle of gait is 15-degree dorsiflexion during the start of stance phase and 20-degree plantar flexion at the time of starting the swing phase.

A study was done by Benjamin F. Mentiplay et al., according to it, 3D gait analyses is used to know gait patterns and examine the changes. Currently, many types of gait analysers exist. The data was collected and analysed in Visual3D. [33]

As per the above study, results considered as ultimate variables of kinematic and kinetics of hip, knee and ankle joint and CGM is commonly used 3d-system for gait analysis. CGM has few markers set which helps in quick patient preparation. CGM required minimum computational knowledge as it has fewer markers to trace the data.[33]

Because of fewer markers, CGM cannot provide the potential data using 3 degrees of freedom that constrained about an additional defined joint centre and improper assigning of markers in CGM have a significant impact on the kinematic result. Addition of Cluster-based marker sets overcomes the limitation.[33, 34, 35]

When compared with CGM, these sets are not as much as dependent on precise alignment of the markers because the data detected based on clusters tracking

the segment by allowing six-degree-of-freedom. They are more accurate theoretically.[33, 34, 35, 36]

The only problem is that they are less practical & more cumbersome for participant preparation time & data analysis. [38]

Previous studies have shown sagittal plane similarity between CGM and cluster-based marker set, but coronal and transverse plane data is not similar.

CGM uses direct kinematics computation theory by assuming markers aligned and attached firmly to segments of limb and check the 3-degree-of-freedom.[39, 40]

Two other computerized theories available are 1) segment optimization using 6 degrees of freedom 2) Global optimization

Inverse kinematics a/k/a global optimization is used to decrease the error and it computes the proper match between the actual markers and the model determined markers. IK allows analysing exact marker locations to eliminate errors and maintain its accuracy even in skin defects. [38. 39]

Using a computer and video camera-based gait model system, and with the help of different markers, we can visualize various angles of different joints and segments of the limb. Later, proper marker position was improved and explained by 6 degree-of-freedom and global optimization system.[42, 43]

A. Gokeler et al. did meta-analysis study using PRISMA guiding principles which stated about the existing biomechanical defect of ACL reconstructed knee. They analysed it by gait analysers at mean deviation period of two and half years and found defects in the frontal, sagittal and transverse plane. They also stated to

improvise the physiotherapy protocols post ACL surgery to decrease biomechanical changes in gait which had the worst impact on joint. Based on this meta-analysis some parameters showed different results even after years of surgery, in them initial recovery knee flexion range from 0.1 degrees to 8.1 degrees compared to healthy knee range from 3 to 4 degree, accurate improvement of knee abduction of ACLR knee with patellar tendon-bone graft compared to hamstring graft, questionable outcome noted in knee rotation of all the patients even after years of surgery. [80]

A study by Rita M. Kiss, Zsolt Knoll et al., using mechanical AXIOM method for knowing the position of limbs by ultrasound-based markers and positional malalignment, helps orthopaedic surgeons for suggesting physiotherapy and for defect improvisation. This study mainly discussed about intact ligament movement in each gait cycle and to know the relative difference of Spatio-temporal parameters in men and women using a 3D model which developed by Winter. [74]

Healthy gait is characterised by optimal movement variability, which allows for flexibility, adaptability, and the ability to respond to unpredictable situations.

Kate E. Webster et al., mainly dealt with gait issues in patients with graft dependent problems by using 3D motion detector (KT-1000) in 17 patients who underwent ACLR with BPTB graft and in 17 patients with hamstring tendon, found smaller external knee flexion in 7 patients in BPTB group compared to healthy limb and in 5 patents of hamstring group and external knee extension less in 9 patients of BPTB group and 4 patients of hamstring group but at the end of the study they stated that these defects are also because of donor site morbidity and varies with patients and their activities.[60]

Micheal Yunes et al. did meta-analysis study about the comparison of ACLR with BPTB graft, semitendinosus graft and gracilis graft and their surgical procedure, concluded that patients treated with BPTB graft are stable than semitendinosus or gracilis tendon grafts using KT testing and clinical examination and also found improvisation of patient's stability by comparing with a healthy knee. In this study 75% of the patients with BPTB graft improved with 12% complication rate and 64% of patients with ST/G tendon graft with the same complication rate of 12%, but overall 18% more improvement in BPTB group compare to ST/G group.[59]

K. Eriksson et al., done study on patients treated with BPTB graft with interference screw fixation and semitendinosus graft with endobutton fixation for ACL injury which stated both the grafts shows same stability by asking different questionnaire and available scales like IKDC, Lysholm scale and patellofemoral pain score. In 143 patients who got treated with above-stated surgery (70 with BPTB and 73 with ST graft) had no regret for the surgery, in that 2 patients with BPTB graft injured due to high-velocity trauma and 3 patients with ST graft injured due to low-velocity trauma, with 1 patient with ST graft ended with deep-seated infection and BPTB graft with fracture of the posterior aspect of femur tunnel but with the excellent outcome of Lysholm score of 96.[63]

Normal human gait consists of wide variabilities; that is why the neuromuscular system in humans is flexible and can sustain a range of stress.[65, 66]

Though the biomechanics of both the autografts are different, there are no studies related to the variability of gait in different ACL reconstruction techniques. So, we hypothesized that ACLR using either PAT/ST graft would affect the gait overall in the reconstructed as well as the healthy contralateral knee.[67]

Moraiti et al., suggest that there is a lot of divergence in the gait of both groups of reconstructed knees and their contralateral healthy knees. Comparison between the BPTB and ST graft using Lye could be an essential tool for the measurement and evaluation of many conditions that affect the neuromuscular system. But the outcome of each type of reconstruction in terms of gait variability remained the same. We conclude that ACL reconstructed knees could lead to the early development of future pathologies. They are susceptible to injuries due to a lot of divergence in normal human gait. Though the gait variability of both groups is the same in our study, further research is required to conclude the debate of superior autograft.[68]

ACL injuries disturb the normal anatomy as well as the physiology of the knee joint. This lead to an impairment of biomechanics knee joint in context with kinematics and neuromuscular control.[65, 66, 69]

Though current ACL reconstructions restore the anatomy, it won't restore the biomechanics completely. In their study, there is a problem of excessive tibia rotation in high demanding activities when it comes to both anterior as well as rotational loading of the knee. It is consistent with every current ACL reconstruction irrespective of the autografts selected. [69]

These unrestored biomechanics may result in excessive loading over the knee, which may subsequently cause early changes of osteoarthritis. Such imbalance may also affect the sports performance after a knee injury and increased chances of re-injury. In our recommendations, we focus on further research for the development of advanced surgical procedures that could restore the near-complete biomechanics of the knee to delay future knee problems. [69, 70]

Kate E Webster et al. conducted a controlled laboratory study to observe gait patterns after anterior crucial ligament reconstruction, which is related to graft type.[58]

They compared three groups in which ACL reconstructed with a patellar tendon in one group and second group ACL reconstructed with Hamstring tendon, and both of these groups matched with controls which are the third group.[57, 59]

This controlled laboratory study observed differences in the knee movements, which are related to graft type. The external knee flexion during midstance comparatively lesser than that in the control group, in sixty-five percentage of patients in the patellar tendon group and twenty-nine percentage of patients in the hamstring tendon group. [50]

These differences in knee biomechanics after anterior cruciate ligament reconstruction are related to donor graft type and site.[61, 62, 63, 64]

In a population with ACL rupture and post-operative ACL rupture, early development of OA knee is more common, but it depends on different aspects like obesity, physical activity, and time of surgery post ACL rupture and gender of the patients. Patients who undergo ACL reconstruction, development of early OA progression is less. In knee, ACL injury is one of the most common traumatic musculoskeletal injuries which are seen in different sport players and its tear is associated with degenerative changes in the long run and physical activity of affected knee. Osteoarthritis of the knee described as a disease of "wear and tear" which is seen in the aged population. Based on follow up's data in different individuals with ACL rupture progression of early OA knee is more common, and gait analysis is one of the best methods to categorise them and treat accordingly. [54, 55]

Individuals with osteoarthritis knee and ACL rupture have changes in different parameters of gait analysis, and this had proven successful by many researchers and the changes are due to dynamic frontal plane malalignment and axial malalignment of the knee.[46, 47]

Even these changes in mechanics are seen in asymptomatic and low-grade OA knee population using gait analysis. These malalignment of frontal plane mechanics are due to an increase in displacement between ground GRF and KJC.[48, 49, 50,51,52,53]

After ACL rupture, development of osteoarthritis knee is more common because of the loss of axial rotation, control over medial compartment of the knee. By using gait analysis we can establish the different grade of osteoarthritis knee and mechanism of OA due to impact of ACL rupture. [54, 55]

Development of osteoarthritis knee in different individuals who underwent ACL reconstructive surgery increased due to severe knee abduction and usage of different grafts compared with a control group. Also, based on age, gender, activity level and BMI.[56]

In 2011, a study was done by Sdtsivgoulis et al., on 20 male patient's changes in gait before and after ACL reconstruction. Gait analysis was measured using a triaxial accelerometer, and data was analysed by the GEDEM (Gait Evaluation Differential Entropy Method) to determine gait variability. They assessed pain by visual analogue scale and Oswestry Disability Index and the International Knee Documentation Committee score for functional ability. Pain and functional ability scores improved after surgery compared with before surgery. [79]

METHODOLOGY

SOURCE OF DATA:

Data will be collected from patients who will undergo anterior Cruciate ligament tear reconstruction surgery with patellar tendon-bone graft in KLE'S Dr.Prabhakar Kore Hospital & Medical Research Centre and Charitable Hospital in Belagavi over one year from 1st January 2019 to 30th December 2019.

METHOD OF COLLECTION OF DATA:

STUDY DESIGN:

A one-year hospital-based observational study.

SELECTION CRITERIA:

INCLUSION CRITERIA:

- Patients with ACL deficient knee
- Age 18 and above

EXCLUSION CRITERIA:

- Patients with generalised ligamental laxity
- Patient not fit for surgery/ not willing for surgery
- Patient associated with other ligament and bony injuries around knee joint
- Patient with learning disabilities

METHOD:

Lower limb motion will be tracked using a motion capture system with one position sensor, equipped with embedded infrared cameras. The system will track the position and orientation of clusters of active markers. In Simple Helen Hayes protocol there are 6 phases

1) **Subject preparation**: (anthropometric measurements like ASIS breadth, pelvic depth, leg length, knee diameter, malleolus width, height and weight are marked) and markers are attached on different parts of the body. In Modified Simple Helen Hayes 15 markers are attached 3 on the pelvis, 2 on the thigh, 2 on each shank, and 2 on each foot, this version is used to evaluate lower limb and pelvis behaviour.
2) **Acquisition phase**: a) Standing task
   b) Walking task
3) **Elaboration phase:**
   a) Tracking
   b) Calculation protocol selection
   c) Events
4) **Reporting phase**
   a) Mean Spatio-temporal parameters
   b) Gait profile score
   c) Gait variable score
   d) Gait deviation index

5) **Checking marker location**

6) **Helen Hayes With Medial Markers (optional).**

After doing gait analysis, main parameters observed in this study are

a) Knee valgus varus in degree

b) Knee flexion-extension in degrees

c) Ankle dorsal-plantar flexion in degrees

d) Knee rotation in degrees

All temporal parameters

1. Stride time (sec)
2. Stance time (sec)
3. Swing time (sec)
4. Stance phase (%)
5. Swing phase (%)
6. Single support phase (%)
7. Double support phase (%)
8. Mean velocity (m/s)
9. Mean velocity (%height):
10. Cadence (steps/min)

The patients who are undergoing anterior cruciate ligament tear reconstruction with patellar tendon-bone graft in KLE'S Dr.Prabhakar Kore Hospital & Research Centre and Charitable Hospital, Belagavi will be examined thoroughly, and necessary investigations will be done. Then the patients who are being assessed will be explained in detail about the study and informed written consent would be taken. The

patient will have to be operated as per fitness for the surgery. Anterior Cruciate ligament tear reconstructions with patellar tendon-bone graft and gait analysers used for the study are BTS SMART GAIT ANALYSER BY FOLLOWING SIMPLE HELEN HAYES PROTOCOL. [77, 78]

PHYSIOTHERAPY: Modified Wilk's protocol

Pre-operative Phase:

- Concentrated on decrease of swelling, pain, inflammation, improvising range of motion and usage of knee brace for stability.

Elevation/Cryotherapy

- Apply ice twenty minutes of every hour, elevate leg with the knee in full extension (knee must be above the heart).

GAIT ANALYSIS: Once the patient is fit for surgery and restoring all pre-operative goals like diminished swelling, inflammation, pain, restoring full range of motion mainly full extension and after restoring full muscle activation of the lower limb, and explaining the surgical procedure and explaining different modalities of treatment and complications regarding different surgeries and using different grafts and getting informed written consent from the patient and patient attenders, the patient is subject to do gait analysis preoperatively and 9 months after postoperatively and determine the clinical outcome by observing both the data. Gait analyses are done by using BTS SMART GAIT ANALYSER FOLLOWING SIMPLE HELEN HAYES PROTOCOL in patients of Anterior Cruciate ligament tear reconstruction with a patellar tendon-bone graft.

POST-OPERATIVE PHYSIOTHERAPY PROTOCOL: - MODIFIED WILK'S PROTOCOL

FIGURE 1: PELVIMETER FOR MEASURING DIAMETERS OF PELVIS AND OTHER LOWER LIMB SPOTS OF THE SUBJECT.

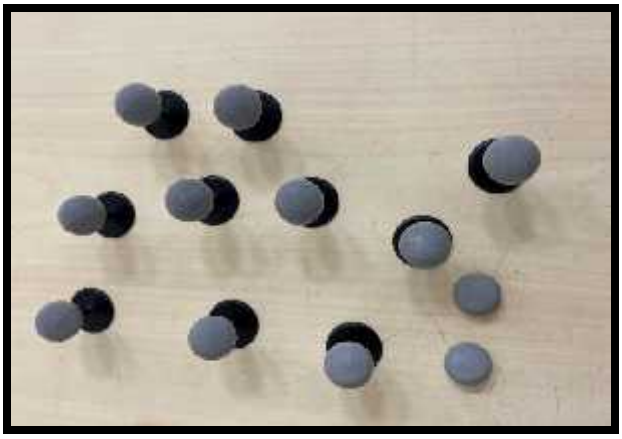

FIGURE 2: SKIN MARKERS WHICH CAN BE DETECTED BY SMART-DX AND VIXTA CAMERAS

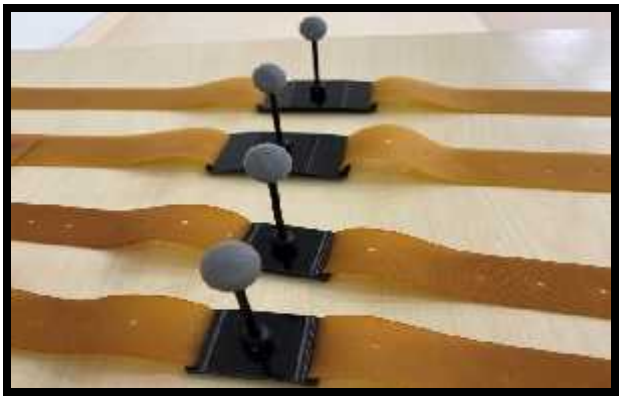

FIGURE 3: SKIN MARKERS WITH BODY STRAPS WHICH CAN BE DETECTED BY SMART-DX AND VIXTA CAMERAS

FIGURE 4: VIXTA CAMERAS: FOR ANALYSIS FROM DIFFERENT VIEWING PERSPECTIVES

FIGURE 5: SMART-DX 6000 CAMERA: HIGH PRECISION OPTOELECTRONIC SYSTEMS FOR MOTION ANALYSIS

FIGURE 6: GAIT LAB

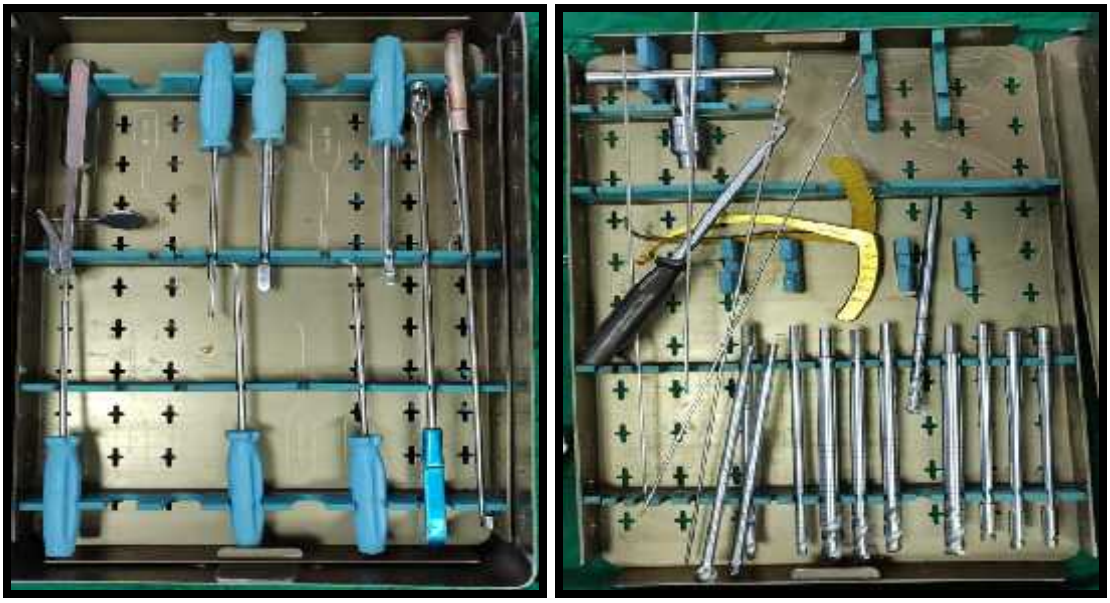

FIGURE 7: ACL RECONSTRUCTION INSTRUMENT SET

FIGURE 8: GRAFT SIZER

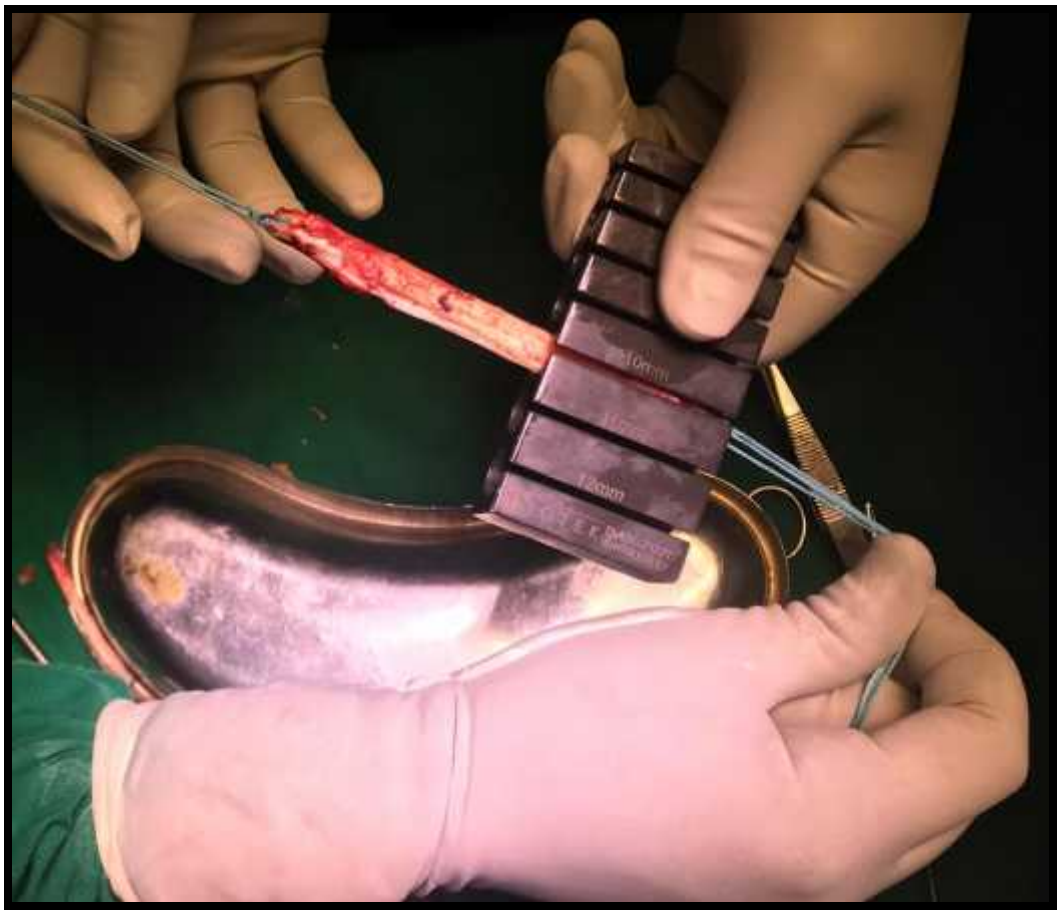

FIGURE 9: SIZING PATELLAR TENDON BONE GRAFT, ENDS OF THE GRAFT ATTACHED TO ETHIBOND

FIGURE 10: TITANIUM INTERFERENCE SCREWS

OBSERVATIONS

Our one-year hospital-based observational study involves 15 patients with complete anterior cruciate ligament tear with pre-operative gait analysis and reconstruction of the anterior cruciate ligament with a patellar tendon-bone graft and follow-up of 9 months with post-operative gait analysis.

Epidemiology: In this study, fifteen male patients are involved. The patient's age is above 18 years as per inclusion criteria. In these 15 patients, 40% (6 patients) are affected with a right anterior cruciate ligament tear, and 60% (9 patients) are with a left anterior cruciate ligament tear.

Mechanism of injury:

The causes of an anterior cruciate ligament tear in these 15 patients had a different mechanism of injury, i.e., 2 patients had a history of fall while playing football, 8 patients had a history of an RTA, and rest of them had a different history of fall and twisting injury of the knee.

Co-morbidities or associated injuries:

Two patients had hypertension and diabetes mellitus on treatment, two other patients had hypertension on treatment, and other 11 patients are without any co-morbidity.

Assessment:

The patient was subjected to do gait analysis preoperatively and 9 months after postoperatively and determines the clinical outcome by observing both the data. Gait analyses are done by using BTS SMART GAIT ANALYSER FOLLOWING SIMPLE HELEN HAYS PROTOCOL in patients of Anterior Cruciate ligament tear reconstruction with a patellar tendon-bone graft.

STATISTICAL ANALYSIS

Calculation of Sample size formula:- Based on parent article considering various factors the sample size would be Standard deviation (SD) of 73.95 units Power of 80% Z beta 0.84 Z alpha 1.96 Level of significance of 5% Implementation of

Formula:

$n = 2 + (SD/d)^2 (Zalpha+Zbeta)^2$

$=2 + (73.95/82.81)^2(1.96+0.84)^2$

$=2 + (0.89)^2(2.8)^2 =2+9.968$

=12 pairs (12 pre-operative and post-operative)

SAMPLE SIZE: 12PAIRS

DISCUSSION:

- Gait is characterised by optimal movement with variability, which allows stable response to unpredictable conditions. Gait analysis enhances accurate assessment of gait variations than visual gait assessment in spatial orientation. It is an accepted research tool in assessing gait patterns.[81]
- 3D gait analysis evolved over time. The CGM is less computationally intensive as there are some markers to track, and can result in a less tag drop out and switching.[33, 34, 35] Biomechanics of knee need to be understood throughout the regular events. This article provides a significant review of the pros associated to gait in patients following ACL Reconstruction.[44, 45]
- The measurement of interest in the study done by Wren TA et.al, are to assess the kinetic variables seen during gait in patients after ACLR. The adduction movements of the knee are a prime cause of osteoarthritis after the reconstructive procedure. Biomechanical deficits evidenced during gait in ACL reconstructed patients are pervasive. The ACL reconstructed group showed reduced ROM of the knee one year after reconstruction. [81]
- Wren TA et al, suggest that there is much divergence in the gait of both groups of reconstructed knees and their contralateral healthy knees as ACL reconstruction correspondingly pretends the structure of gait unevenness in the intact contralateral limb.
- In comparison between the BPTB and ST graft using LyE could be an essential tool for the measurement and evaluation of many conditions that affect the neuromuscular system. But the outcome of each type of reconstruction in terms of gait variability remained the same.[81]

- Xiaobing yu et al. conducted a study considered a three-dimensional gait analysis pre and post ACL injury. A prospective cohort study was done, including 15 individuals in each group -a control group and a study group. It evaluated the features of the gait cycle in ACL injury and healthy groups. FERA (flexion-extension rotation angle), VERA (Varus eversion rotation angle), IERA (internal and external rotation angle) was analysed throughout the gait cycle including swing and stance phase.[71]
- He noticed that ACL study group has significantly more extensive range (in swing phase, knee flexion angle, external tibial rotation and varus has reached a maximum and in stance phase, extension, internal tibial rotation and varus angles reached maximum) when compared with control group. Thus he concluded that FERA (flexion-extension rotation angle), VERA (varus eversion rotation angle), IERA (internal and external rotation angle) can be used as a diagnostic reference for ACL injury and provides significant guidance for post-op rehabilitation.[72]
- In 2002 a study was done by David M. Hooper et. Al., about knee task after ACL reconstruction in the dynamic activities of walking and usage of stairs. During straight walking, throughout mid-stance patients placed their knee's in external flexion torque, indicating prevention of quadriceps muscle in gait. When ascending and descending stairs the ultimate external flexion torque placed in battered knee was considerably less than unbattered knee. Wounded Knee produced substantially less power than the safe and sound knee while climbing stairs, but this difference was not significant when descending stairs. Patients with ACL reconstructed knees do not have quadriceps avoidance gait during level walking. Furthermore, biomechanical parameters describing the

stance phase of level walking are nearly equal in effected and intact sides within one year after surgery.[73]

- In 2003 Zsolt et.al, did the study on 25 Anterior Cruciate ligament tear patients before ACL reconstruction and six weeks, four months, eight months and 12 months after ACL reconstruction using a bone-patellar tendon-bone graft. Utilising 3-dimensional US (ultrasound) based system, gait analysis was done. Lower limb kinematic data is recorded. The results suggested that advancement of the quadriceps muscle avoidance pattern is not as much as of previous literature. Lower extremity gait significantly altered in ACL deficient and post ACL reconstruction knee, the gait variables shift towards the regular value pattern and the restitution of pre-injury gait variables including the normal biphasic of muscles - takes at least eight months to occur. Patients with anterior cruciate ligament tear showed an amplified knee extension throughout the stance and reduced flexion throughout the swing phase.[74]
- In March 2009 retrospective study was done by Massimo bacchini et al., in which, after a follow up of 6 months in young adult patients who are not concerned with sports, to know the persisting defects of ACL reconstruction by Kenneth-jones were judged by gait analysis and clinically. In this study, total 8 patients who underwent elective ligament rebuilding by Kenneth-jones were assessed between the 5^{th} and 7^{th} month post-surgery with the clinical investigation, gait analysis with the EL.I.Te. System and including the Hughston clinical subjective knee questionnaire. Whereas in the study, gait analysis revealed a reduction of ACL defense mechanism during initial stance phase, but the post operated patients exhibited more incredible difficulty in muscle recruitment. This study emphasizes the importance of gait analysis to

reveal deficits persisting after the rehabilitative treatment and then to take measures for protecting the integrity of the neo-ligament and also after ACL reconstruction, for a correct rehabilitation gait analysis data is needed.[75]

- In 2004, a randomised control study was done by Michael J. Decker et.al, in which they assessed the variables of gait of two rehabilitation protocols that had undergone ACL Reconstruction with bone-patellar tendon-bone graft. In this study, sixteen patients were randomly subdivided into two groups and consigned to two different gait rehabilitative protocols over six weeks of training 1] FORCE DRIVEN HARMONIC OSCILLATOR 2] PREFERRED STRIDE FREQUENCY.
- Gait reorientation with the FDHO model showed perfections in lower extremity loci, hip and knee extensor angular impulse, and work parameters. Gait reorientation with PSF validated no statistical improvement in higher mid-stance knee than FDHO in which more excellent rates of development is seen in mid-stance phase.[76]
- Based on statistical analysis consolidated percentage of all the gait parameters traced by gait analysis using BTS SMART GAIT ANALYSER following Simple Helen Hayes protocol in pre and post operative patients, excellent improvement of knee valgus-varus and swing time was seen in 100% (15) of the post operative patients. In contrast, other parameters with excellent improvement in post operative patients are knee rotation in 20% of the patients, knee flexion-extension in 80% of the patients, stance time in 13.33% of the patients, stance phase in 20% of the patients, swing phase in 73.33% of the patients, single support phase in 13.33% of the patients, double support phase in 6.67% of the patients and finally mean velocity (m/s) in 6.67% of the

patients.

- Gait parameters which are improved than pre-operative data are knee rotation in 80% of the patients, knee flexion-extension in 20% of the patients, ankle dorsal-plantar flexion and stride time in 100% of the patients, stance time in 86.67% of the patients, stance phase in 80% of the patients, swing phase in 26.67% of the patients, single support phase in 66.67% of the patients, double support phase in 86.67% of the patients, mean velocity (m/s) in 93.33% of the patients, mean velocity (%height/s) in 73.33% of the patients and cadence in 80% of the patients.
- Some parameters which are not improved even after following proper physiotherapy protocols are single support phase in 20% of the patients, double support phase in 6.67% of the patients, mean velocity (%height/s) in 26.67% of the patients and cadence in 20% of the patients.
- After comparing overall pre and postoperative data during this study of gait analysis using BTS SMART GAIT ANALYSER following Simple Helen Hayes protocol is considered to be the sophisticated tool to decide the outcome of surgery, which muscles are to be strengthen and what are the clinical outcomes in patients enduring ACL reconstruction with a patellar- tendon-bone graft.

CONCLUSION

Anterior Cruciate Ligament is one of the prevalent ligament injuries during twisting injury of the knee due to different reasons like RTA, sports injury, etc., which leads to change in biomechanics of the knee and abnormal gait pattern. The bone-patellar tendon-bone graft is one of the stable and standard grafts for ACL reconstruction. There is a lot of literature stating that BPTB graft is strong graft and also helps in the anatomic reconstruction of the articular area, axis, rotation and connection reestablishment for the femur and tibia. Patellar tendon-bone graft acts as a bridging combination and has early functional rehabilitation. Promising results obtained by patellar tendon-bone graft are due to fast healing by bone to bone, vascularisation protection, reduced complication rate, reduced primary or secondary grafting requirements, and shortening of the operative time and also to increased resilience to mechanical stress, but most of the studies are patient or investigator biased because it depends on clinical examination and scoring system based on the questionnaire. There is significantly less literature to know the efficacy of technical accuracy, diagnostic accuracy, diagnostic thinking and treatment efficacy, outcome efficacy. In our study, we have collected pre-operative gait analysis data of unilateral ACL tear patients using BTS- SMART gait analyzer and the patient was subjected to ACL reconstruction with BPTB graft. Patient and physiotherapy team was advised to follow WILK'S physiotherapy protocol for 9 months and adviced to repeat the gait analysis. There are multiple parameters in gait analysis, but we preferred the main parameters which affect the biomechanics of knee in the affected limb and compared the pre and post-operative data of patients who underwent ACL reconstruction with BPTB graft.

Based on our study we can easily state that gait analysis data generated using this system is one of the sophisticated way to know the technical efficacy of the surgery, diagnostic thinking, treatment and outcome efficacy and there are many types of grafts but BPTB graft is very helpful in normalizing many parameters of gait, returning to daily activities/sports activities with significantly less requirement of revision surgery and less donor site comorbidity. This dissertation mainly discussed about gait analysis in ACL tear patient and gait analysis of the same patient who underwent ACL reconstruction with bone-patellar tendon-bone graft but has not discussed any other existing grafts and their outcomes. Considering this study as a classic example, we can analyze the effectiveness of different grafts in further studies.

SUMMARY

- This one-year hospital-based observational study was conducted in 15 patients.
- The age of patients is above 18yrs.
- Among 15 patients, right knee is affected in 6 (40%) patients and left knee is affected in 9 (60%) patients. All patients with ACL tear underwent ACLR with BPTB graft.
- Pre operative gait analysis is done in ACL tear patients and in same patients post-operative gait analysis is done after 9 months of follow up.
- During the 9 months of follow up, Wilk's protocol is used for physiotherapy.
- Gait analysis was done using BTS-Smart gait analyzer following Simple Helen Hayes Protocol.
- Based on statistical analysis consolidated data, there is an improvement in different variabilities of gait cycle like knee valgus – varus in degrees, knee rotation in degrees, knee flexion-extension in degrees, stride time (s), stance time (s), swing time (s), stance phase (%), swing phase (%), single support phase (%), double support phase (%), mean velocity (m/s), mean velocity (%height/s), cadence (steps/min).
- Some parameters which are not improved are single support phase in 20% of the patients, double support phase in 6.67% of the patients, mean velocity (%height/s) in 26.67% of the patients and cadence in 20% of the patients.
- Based on our study we can easily state that gait analysis data generated using this system, is a sophisticated way to know technical efficacy of the surgery, diagnostic thinking, treatment and outcome efficacy and there are many types

of grafts but BPTB graft is very helpful in normalizing many parameters of gait, returning to daily activities/sports activities with significantly less requirement of revision surgery and less donor site comorbidity.

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ANNEXURE I-CONSENT FORM

INFORMED CONSENT

Title of Research Study:

"PRE AND POST OPERATIVE GAIT ANALYSIS IN PATIENTS UNDERGOING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING PATELLAR TENDON BONE GRAFT– A ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY"

Dr.
Post-graduate resident,
Department of Orthopaedics,
J.N. Medical College,
K.A.H.E.R, Belagavi 10.
Ph. No. 8970260433

Dr.
Professor
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INTRODUCTION AND PURPOSE:

- Gait defines as the locomotion achieved by movement of human limbs. In humans it is achieved by bi-pedal and bi-phasic forward propulsion which has meandrous movements with least possible expense of energy.
- Gait has three components :

1. Progression
2. Stability
3. Energy conservation
    1. PROGRESSION: The primary force created by lower limb to attain forward fall of body weight while maintaining secondary momentum generated by upper limb through swinging motion.

2. STABILITY: The forward fall is then controlled throughout the phase of the gait while maintaining in upright position. During the stance phase the body is most stable where the ankle, hip and knee are vertically aligned, the stability is maintained by strong ligaments of the hip and knee. The balance between the knee stability and shock absorption is maintained by contraction of quadriceps.
3. ENERGY CONSERVATION: It is calculated by oxygen consumed per meter travelled. Human gait enhances this by reducing the quantity of muscular effort which is referred for walking. This is achieved by co-ordinated pelvic, knee and ankle motion.

- The ligaments of hip and knee play a vibrant role in gait, any injury to these ligaments will alter the pattern of the gait.
- Anterior cruciate ligament is commonly injured and associated with instability of knee which results in alteration in normal pattern of the gait.
- As arthroscopic surgeries for ACL ligament injury emerged in the late 1990's. The analysis regarding gait pattern post reconstruction of ACL has been given a faint importance.
- The instability of post ACL injury is due to change in biomechanics of knee as tibia overrides the femur anteriorly while reclining downstairs or walking on uneven surfaces.
- After introducing 3D-locomotory gait analyser there has been a profound use of this system to analyse the discrepancy in the pattern of gait in ACL injury as well as post ACL reconstruction.
- The emergence of this system has been a helpful boon for the patients who have undergone ACL reconstructive surgery to revert to their normal gait pattern.

- The graft selection for ACL reconstruction has numerous options which comprises of bone patellar tendon bone graft, hamstring graft, allografts and synthetic grafts.
- Among this bone-patellar tendon-bone graft (BPTB), they have high tensile strength and quicker healing capabilities. Though it has post-operative donor site, the merits for reconstruction of ACL with BPTB graft is comparatively better to its demerits.
- The purpose of this study is to determine the best Clinical outcome for **"ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING PATELLAR TENDON BONE GRAFT** "in Orthopaedics department of KLE'S Dr.PrabhakarKore Hospital and Medical Research Centre and Charitable Hospital, Belagavi from 1st January 2019 to 31st December 2019.
- **PROCEDURE:** If you consent to be in this study, the relevant data is collected as per the proforma after the final diagnosis is confirmed. Comparison of pre and post-operative gait analysis data after ACL reconstruction with PTB graft was done. Follow up gait analysis of the patient will be carried at 9 months of ACL reconstruction.

BENEFITS:

1. Strength of the graft comparative to native ACL and nearly equals its stiffness

2. Bony fixation

3. Easily harvested

4. Excellent track record

5. Prompt healing

6. Lower rate of infection

7. Simpler technique and easy to master, learning curve short

8. No need of additional expensive instrumentation

9. Early mobilization of the extremity possible

10. Angular as well as axial stability restored

RISKS:

1. Donor site morbidity

2. Knee stiffness

3. Patellar tendinitis

4. Kneeling pain

5. Tendon rupture (rare)

6. Patellar / tibia fracture

7. Quadriceps weakness

8. Loss of full extension

9. Numbness due to injury to the infrapatellar branch of saphenous nerve

VOLUNTARY PARTICIPATION / WITHDRAWAL:

Taking part in this study is voluntary. I may choose not to take part in this study, or if I decide to take part I can later change my mind and withdraw from the study. My decision will not change the present or future health care or other services that I receive. The investigator or the sponsor may stop my participation in this study. I will tell any important new findings that may change my willingness to continue to take part. If I choose not to take part in the study, I will receive the standard treatment for patients with my condition.

COMPENSATION:

As the subject voluntarily consents to be a part of the study, no compensation will be given.

CONFIDENTIALITY:

All information collected about the subject during the course of the study will be kept confidential to the extent permitted by the law. The code numbers will identify the subject in this research record. Information from this study may be presented but the subjects identification will be kept confidential in any publication.

If any enquiries in the future or in case of study related injury or illness, you may contact following person:**DR. ROOPA BELLAD**Chairperson,Ethical Committee for Human Subject Research,Professor, Department of Pediatrics,Jawaharlal Nehru Medical College,Belagavi- 590010

CONSENT TO PARTICIPATE IN RESEARCH STUDY

"I voluntarily agree to take part in this study by signing below. I may withdraw at any time. I am not giving up any of my legal rights by signing this form. My signature below indicated that I have read this entire consent form or it has been read to me, and had all my questions answered. I will be given a copy of this consent form."

Signature of the Participant or legally authorized representative

Participant's Name: ……

Signature: ……

Name of legally authorized representative: ……..

Signature: …….

Witness's Name:

Signature: ……..

Investigators Name and Signature: …….

Date and Place: ……

ANNEXURE-II

PROFORMA

DEPARTMENT OF ORTHOPAEDICS

JAWAHARLAL NEHRU MEDICAL COLLEGE, BELAGAVI

***Title of Research Study:* "PRE AND POST OPERATIVE GAIT ANALYSIS IN PATIENTS UNDERGOING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING PATELLAR TENDON BONE GRAFT– A ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY"**

PATIENT NO: IP NO:

NAME:

AGE: SEX:

ADDRESS:

OCCUPATION:

DOA: DOS: DOD:

CHIEF COMPLAINTS:

PRESENTING COMPLAINTS:

Pain

Swelling

Instability

Giving away sensation

Stair climbing difficulty

Wound

Deformity

HISTORY OF PRESENT ILLNESS:

Nature of injury:

1. RTA
2. Sports injuries
3. Trivial trauma
4. Assault
5. Others

Mode of injury:

1. Direct
2. Indirect

Duration since injury:

…….days

SIGNIFICANT PAST HISTORY:

a. Joint injuries criteria for generalized ligament laxity –Components of the Beighton scale

1. Passive dorsiflexion and hyperextension of the fifth MCP joint beyond 90°

2. Passive apposition of the thumb to the flexor aspect of the forearm

3. Passive hyperextension of the elbow beyond 10°

4. Passive hyperextension of the knee beyond 10°

5. Active forward flexion of the trunk with the knees fully extended so that the palms of the hands rest flat on the floor.

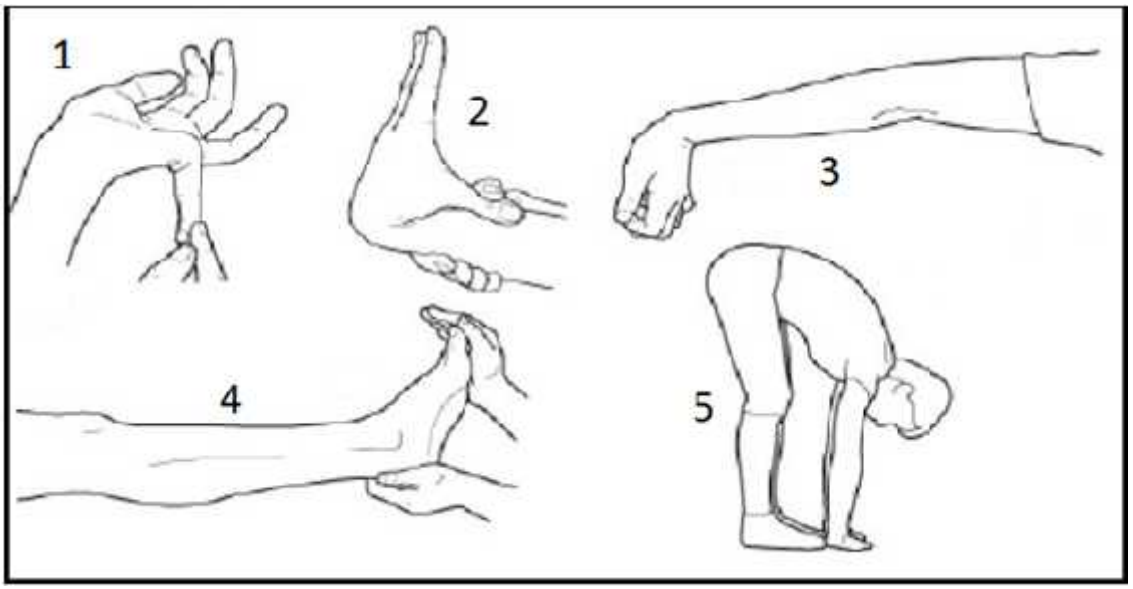


FIGURE 28: Components of the Beighton scale

TOTAL

The first four elements can be given a maximum score of 2, because these are performed bilaterally. The last element is scored with 0 or 1. The maximum score for ligament laxity is 9. A score of 9 means hyperelax. A score of zero is tight. Several researchers appoint a score of 0-3 as normal and a score of 4-9 representing ligamentous laxity. According to child (1986), a score of 4 or more out of 9 indicates generalized hypermobility of the joints .The spinal forward flexion criterion differs from the other criteria in which it measures hamstring flexibility and anatomic proportions to ligamentous laxity. According to the Beighton and Horan criteria, generalized joint laxity is present when four or more of five tests are positive, including contralateral knee hyperextension.

A. History of Diabetes Mellitus, Hypertension, Asthma, Rheumatoid Arthritis, Tuberculosis and other chronic illness

1. Yes
2. No

B. Previous history of anterior cruciate ligament tear

1. Yes

2. No

C. Previous history of any medication received

PERSONAL HISTORY:

Diet : Veg/ Mixed/ Nonveg

Appetite : Increased or Decreased

Habits : Smoking/ Alcohol /others

Bowel & Bladder Habits : Normal or Abnormal

FAMILY HISTORY:

GENERAL PHYSICAL EXAMINATION:

Built : Well/Moderate/ Poor

Temperature Pulse

Blood Pressure Respiratory Rate

Pallor

Cyanosis

Icterus

Clubbing

Pedal edema

Lymphadenopathy

SYSTEMIC EXAMINATION:

Cardiovascular System Examination:

Respiratory System Examination:

Per Abdomen Examination:

Central Nervous System Examination:

LOCAL EXAMINATION:

INSPECTION:

Lower Limb Involved RIGHT LEFT

Attitude

Skin: Blebs / Ecchymosis / Avulsed / Bruise

Swelling

Deformity

PALPATION:

Tenderness

Abnormal mobility

Peripheral Pulses: Dorsalispedis / Posterior Tibial/ Anterior Tibial

Neurovascular Deficits :(Tingling / numbness / Power)

1. Yes
2. No

Presence of any associated injury:

1. Yes
2. No

If yes specify

RANGE OF MOVEMENTS:

Knee joint movement

SPECIAL TESTS:

Anterior drawer test

Posterior drawer test

Lachman's test

McMurray's test/ Apley's Grinding Test

Pivot shift test

Jerk test

Valgus stress test

Varus stress test

RELEVANT INVESTIGATIONS:

a) Blood: Hb%, TLC, DLC, ESR

b) Urine: Albumin, Sugar, Microscopy

c) FBS, RBS

d) Serum Creatinine, Serum Uric acid, Blood Urea

e) HIV, HBsAg

f) ECG

g) X-Ray Knee Joint with distal third femur Antero-posterior view

h) X-Ray Knee Joint with distal third femur lateral view

i) If affordable, CT Scan with 3D view of Knee Joint with distal third femur

DIAGNOSIS:

a) X-ray of affected knee joint

b) MRI of affected knee joint

TREATMENT:

FIRST AID: 1. YES 2. NO

a) Fluid Replacement

b) Immobilization of the Injured Limb

c) Analgesics

d) Antibiotics

DEFINITIVE TREATMENT:

a) Relevant Investigations and Medical Fitness for Surgery

1. Yes

2. No

b) Anaesthesia

General

Spinal

Combined spinal epidural anesthesia

c) Graft used

Patellar tendon bone graft

1) Length of graft

2) Femoral end of graft

3) Tibial end of graft

4) Position of femoral tunnel 11'O clockor 2'O clock

d) Antibiotic Therapy - 1. Pre-operative 2. Post-operative

e) Analgesics

f) Screws used or not if yes, specify the type

g) COMPLICATIONS:

Intraoperative 1) YES 2) NO

- Iatrogenic fracture 1) patella

2) Maisonneuve fracture {spiral fracture of the proximal third of the fibula associated with tear of the distal tibiofibular syndesmosis and the interosseous membrane.}

Postoperative Complications:

Immediate: 1) YES 2) NO

- Bleeding
- Infection
- Nerve damage
- Compartment syndrome
- Deep vein thrombosis

Duration of stay in hospital:

Range of movement of knee joint at discharge:

Flexion Extension

Physiotherapy: Modified Wilk's protocol

Knee joint

Ankle and active toe movements

Static quadriceps exercises

Mobilization of knee and hip

Non weight bearing crutch walking/ walker

Time of full weight bearing

Follow up:

Date:

Serial no. :

Time since surgery:

Clinical union

Range of movements

Gait analysis

Final Deformity: Angulation Varus/ Valgus

Anterior / Posterior

Final Result: Excellent Improvement / Improved than pre-operative data / Not improved.

To be evaluated by BTS SMART GAIT ANALYSER BY FOLLOWING SIMPLE HELEN HAYES PROTOCOL pre-operative and 9 months after ACL reconstruction and rehabilitation using MODIFIED WILK'S PROTOCOL.

ANNEXURE-III ETHICAL CLEARANCE LETTER

K.L.E. ACADEMY OF HIGHER EDUCATION AND RESEARCH
(Deemed – to- be- University)
Accredited 'A' Grade by NAAC (2nd Cycle) Placed in Category 'A' by MHRD (GoI)
JAWAHARLAL NEHRU MEDICAL COLLEGE,
NEHRU NAGAR, BELAGAVI-590010 (KARNATAKA-INDIA)
Website: http//www.jnmc.edu
E-Mail : dome@jnmc.edu
Phone: (+ 91-(0)831 Office : 2472550
Principal: 2471701
Fax No. +91 (0)831 – 2470759

Ref: MDC/DOME/ 29 **Date: 24/11/2018**

To,

Dr.
PG student in Orthopaedics,
J.N.Medical College,
BELAGAVI.

Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled **"PRE AND POST OPERATIVE GAIT ANALYSIS IN PATIENTS UNDERGOING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING PATELLAR TENDON BONE GRAFT – A ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY",** is ethical and justifiable. The proposed research project has been cleared by the JNMC Institutional Ethics Committee on Human Subjects Research.

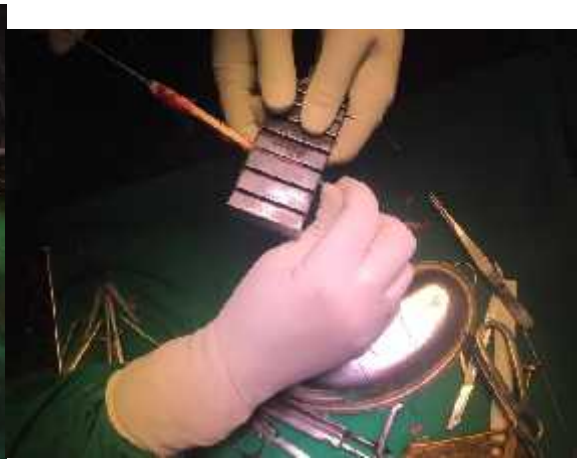
(Dr. Arathi Darshan)
Member Secretary
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

(Dr. Koopa M Bellad)
Chairman,
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

ANNEXURE IV–PHOTOGRAPHS

CASE - 8

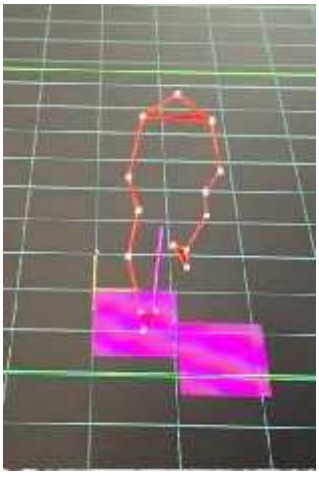
A. KNEE POST HARVESTING CENTRAL 3RD BPTB GRAFT



B. SIZING BPTB GRAFT

C. SUBJECT WALKING ON FORCE PLATE {PLATFORM} SIDE AND ANTERIOR VIEW

D. SUBJECT WALKING ON FORCE PLATE {PLATFORM} POSTERIOR VIEW



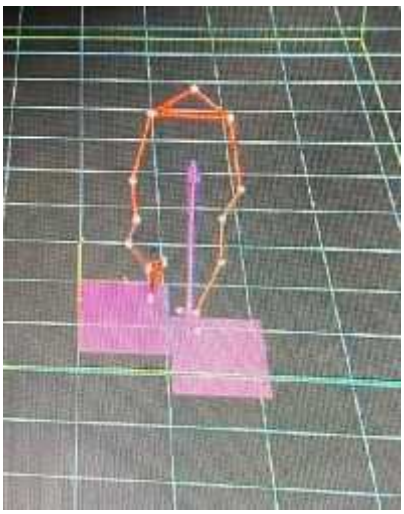
E. 3D VIEW WHILE GAIT ANALYSIS

CASE - 10

A. SUBJECT WALKING ON FORCE PLATE {PLATFORM} ANTERIOR VIEW

B. SUBJECT WALKING ON FORCE PLATE {PLATFORM} SIDE VIEW

C. SUBJECT WALKING ON FORCE PLATE {PLATFORM} POSTERIOR VIEW



D. 3D VIEW WHILE GAIT ANALYSIS

E. MARKING OF CENTRAL 3RD BPTB GRAFT

F. HARVESTED BPTB GRAFT

CASE - 11

A. SUBJECT WALKING ON FORCE PLATE {PLATFORM} ANTERIOR VIEW

B. SUBJECT WALKING ON FORCE PLATE {PLATFORM} SIDE VIEW

C. SUBJECT WALKING ON FORCE PLATE {PLATFORM} POSTERIOR VIEW

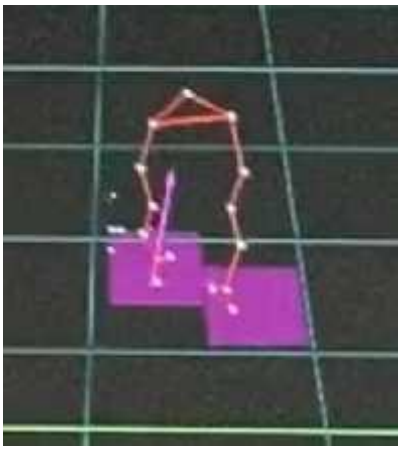
D. 3D VIEW WHILE GAIT ANALYSIS

E.CREATING FEMORALTUNNEL FOR BPTB GRAFT PLACEMENT

CASE - 13

A. SUBJECT WALKING ON FORCE PLATE {PLATFORM} ANTERIOR VIEW

B. SUBJECT WALKING ON FORCE PLATE {PLATFORM} SIDE VIEW



C. 3D VIEW WHILE GAIT ANALYSIS

D. MARKING OF CENTRAL 3RD BPTB GRAFT

E. HARVESTED BPTB GRAFT

ANNEXURE – V_d

KEY TO MASTER CHART

Sl.no	**:**	**Serial number**
RLL	**:**	**Right lower limb**
LLL	**:**	**Left lower limb**
Hb	**:**	**Hemoglobin**
Gm/dl	**:**	**Grams per deciliter**
HTN	**:**	**Hypertension**
DM-2	**:**	**Diabetes mellitus**
RTA	**:**	**Road traffic accident**
I.P NO	**:**	**In patient number**
ROM	**:**	**Range of motion**
%	**:**	**Percentage**
Sec	**:**	**Seconds**
M/S	**:**	**Meters per second**
%height/s	**:**	**Percentage height per second**
Steps/min	**:**	**Steps per minute**
DEG	**:**	**Degree**
+/-	**:**	**Plus or Minus**

Si.NO	AGE (YEARS)	SEX	OCCUPATION	MORBIDITIES	MECHANISM OF INJURY	Hb (gm/dl)	WILLING TO GIVE CONSENT	I . P. NO	AFFECTED LIMB	PRIOR TREATMENT TAKEN (YES OR NO)
1	35	MALE	FARMER	NO	FALL IN FIELD	14.5	YES	867471	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
2	45	MALE	BUSINESS	NO	FALL IN BATHROOM DUE TO SLIP	12.3	YES	870251	RIGHT	CONSERVATIVE TREATMENT TO GET FULL ROM
3	22	MALE	POLICE	NO	RTA FALL FROM 2 WHEELER	16.4	YES	870702	RIGHT	CONSERVATIVE TREATMENT TO GET FULL ROM
4	23	MALE	FARMER	NO	FALL IN PIT	15	YES	879242	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
5	44	MALE	FARMER	NO	FALL FROM LADDER	14.7	YES	888107	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
6	28	MALE	ENGINEER	NO	RTA FALL FROM 2 WHEELER	14.7	YES	888012	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
7	28	MALE	BUSINESS	NO	RTA FALL FROM 2 WHEELER	15.7	YES	897598	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
8	38	MALE	POLICE	HTN/DM-2	SPORTS INJURY	14.5	YES	922746	RIGHT	CONSERVATIVE TREATMENT TO GET FULL ROM
9	26	MALE	BUSINESS	NO	SPORTS INJURY	15.2	YES	956016	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
10	42	MALE	BUSINESS	HTN	RTA FALL FROM 2 WHEELER	15.5	YES	957444	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
11	21	MALE	STUDENT	NO	RTA FALL FROM 2 WHEELER	14.3	YES	957793	RIGHT	CONSERVATIVE TREATMENT TO GET FULL ROM
12	42	MALE	ARMY	HTN	RTA FALL FROM 2 WHEELER	15.8	YES	983928	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
13	57	MALE	ARMY	HTN/DM-2	RTA FALL FROM 2 WHEELER	14.5	YES	991819	RIGHT	CONSERVATIVE TREATMENT TO GET FULL ROM
14	38	MALE	ARMY	NO	FALL FROM STEPS DUE TO SLIP	15.8	YES	999749	LEFT	CONSERVATIVE TREATMENT TO GET FULL ROM
15	39	MALE	ARMY	NO	RTA FALL FROM 2 WHEELER	14.7	YES	1001068	RIGHT	CONSERVATIVE TREATMENT TO GET FULL ROM

PRE-OPERATIVE GAIT ANALYSIS														
STANDING ANGLES				ALL TEMPORAL PARAMETERS										
KNEE VALGUS VARUS IN DEGREES	KNEE ROTATION IN DEGREES	KNEE FLEXION-EXTENSION IN DEGREES	ANKLE DORSAL-PLANTAR FLEXION IN DEGREES	STRIDE TIME(SEC)	STANCE TIME (SEC)	SWING TIME (SEC)	STANCE PHASE (%)	SWING PHASE (%)	SINGLE SUPPORT PHASE (%)	DOUBLE SUPPORT PHASE (%)	MEAN VELOCITY (M/S)	MEAN VELOCITY (% HEIGHT/S)	CADENSE (STEPS/MIN)
NORMAL VALUE (0 +/- 5)	NORMAL VALUE (-10 +/- 5)	NORMAL VALUE (-5 +/- 5)	NORMAL VALUE (0 +/- 5)	NORMAL VALUE (1.1 +/- .09)	NORMAL VALUE (0.65 +/- .07)	NORMAL VALUE (0.44 +/- .05)	NORMAL VALUE (58.98 +/- 1.97)	NORMAL VALUE (40.03 +/- 3.56)	NORMAL VALUE (38.87 +/- 2.57)	NORMAL VALUE (10.27 +/- 3.09)	NORMAL VALUE (1.2 +/- .2)	NORMAL VALUE (80 +/- 5)	NORMAL VALUE (114 +/- 4.2)
(8.1 +/- .2)LLL	(-18.8 +/- .9)LLL	(-4.5 +/- .1)LLL	(3.15 +/- .1)LLL	(1.30 +/- .04) LLL	(0.76 +/-).15) LLL	(0.43 +/- .01) LLL,	(65.37 +/- 2.61) LLL	(35.03 +/- 2.78) LLL	(37.47 +/- 1.9) LLL	(12.01 +/- 1.01) LLL	0.84 +/- .1	59.21 +/- 5.24	95.61 +/- 4.326
(7.9 +/- .1) RLL	(-18.6 +/- .6)RLL	(-4.8 +/- .3)RLL	(3.8 +/- .1)RLL	(1.30 +/- .03) RLL	(0.77 +/- .08) RLL	(0.42 +/- .02)RLL	(63.16 +/- 2.88)RLL	(37.55 +/- 1.94) RLL	(33.38 +/- 16.90) RLL	(13.46 +/- 42.02)RLL	0.89 +/- 0.1	56.46 +/- 3.03	94.22 +/- 1.989
(8.6 +/- .3) RLL	(-18.7 +/- .6)RLL	(-4.6 +/- .2)RLL	(3.13 +/- .1)RLL	(1.27 +/- .02)RLL	(0.79 +/- .05) RLL	(0.43 +/- .02) RLL	(64.45 +/- 2.6) RLL	(36.33 +/- 0.10) RLL	(37.92 +/- 1.67) RLL	(13.98 +/- 1.4) RLL	0.87 +/- 0.1	58.54 +/- 3.44	95.57 +/- 2.294
(8.8 +/- .2)LLL	(-18.2 +/- .5)LLL	(-5.2 +/- .1)LLL	(3.7 +/- .1)LLL	(1.26 +/- .05) LLL.	(0.74 +/- .04) LLL	(0.41 +/- .01)LLL	(63.27 +/- 1.27) LLL	(37.55 +/- 2.01) LLL	(33.1 +/-1.17) LLL	(12.6 +/- 1.1) LLL	0.86 +/- 0.1	57.57 +/- 3.72	95.63 +/- 2.012
(7.9 +/- .3)LLL	(-11.6 +/-.8)LLL	(-5.3 +/- .5)LLL	(3.9 +/- .1)LLL	(1.22 +/- .1)LLL	(0.75 +/- .02)LLL	(0.42 +/- .3)LLL	(64.16 +/- 3.39)LLL	(36.72 +/- 1.24)LLL	(35.33 +/- 2.37)LLL	(13.03 +/- 1.99)LLL	0.89 +/- 0.1	56.86 +/- 5.47	95.11 +/- 2.879
(8.8 +/- .3)LLL	(-19.2 +/- .7)LLL	(-5.0 +/- .1)LLL	(2.9 +/- .1)LLL	(1.27 +/- .07) LLL.	(0.76 +/- .04) LLL	(0.43 +/- .01)LLL	(63.36 +/- 4.05) LLL	(37.98 +/- 1.99) LLL	(32.1 +/-1.08) LLL	(14.6 +/- 1) LLL	0.87 +/- 0.1	57.54 +/- 4.53	96.34 +/- 2.136
(8.6 +/- .3)LLL	(-11.6 +/-.8)LLL	(-4.7 +/- .1)LLL	(3.1 +/- .1)LLL	(1.23 +/- .07) LLL.	(0.77 +/- .04) LLL	(0.43 +/- .03)LLL	(66.29 +/- 0.26) LLL	(34.55 +/- 1.30) LLL	(34.1 +/-2.01) LLL	(12.5 +/- 1) LLL	0.89 +/- 0.1	58.11 +/- 4.73	96.74 +/- 2.212
(6.8 +/- .3) RLL	(-17.8 +/- .6)RLL	(-3.1 +/- .8)RLL	(3.3 +/- .1)RTT	(1.25 +/- .06) RLL	(0.76 +/- .04) RLL	(0.42 +/- .02) RLL	(62.54 +/- 1.45) RLL	(37.03 +/- 1.9) RLL	(37.67 +/- 2.98) RLL	(12.18 +/- 1.48) RLL	0.92 +/- 0.1	57.27 +/- 5.24	96.5 +/- 5.338
(8.9+/- .1)LLL	(-19.2 +/- .7)LLL	(-4.5 +/- .2)LLL	(2.86 +/- .1)LLL	(1.25 +/- .03) LLL.	(0.75 +/- .09) LLL	(0.41 +/- .06)LLL	(65.28 +/- 2.29) LLL	(35.64 +/- 1.25) LLL	(35.1 +/-1.28) LLL	(13.4 +/- 1.02) LLL	0.96 +/- 0.1	57.23 +/- 3.53	95.033 +/- 2.201
(8.3+/- .4)LLL	(-19.2 +/- .7)LLL	(-5.2 +/- .2)LLL	(3.2 +/- .1)LLL	(1.21 +/- .07)LLL	(0.78 +/- .05)LLL	(0.43 +/- .2)LLL	(64.15 +/- 23.42)LLL	(36.82 +/- 1.34)LLL	(34.32 +/- 2.27)LLL	(12.24 +/- 2.01)LLL	0.99 +/- 0.1	57.74 +/- 6.44	94.12 +/- 3.837
(6.9 +/- .4) RLL	(-19.3 +/- .6)RLL,	(-4.6 +/- .7)RLL	(3.6 +/- .1)RTLL	(1.24 +/- .03)RLL	(0.74 +/- .03) RLL	(0.42 +/- .02) RLL	(64.75 +/- 1.5) RLL	(36.35 +/- 1.09) RLL	(32.92 +/- 1.58) RLL	(13.63 +/- 1.3) RLL	0.91 +/- 0.1	56.66 +/- 4.53	95.057 +/- 2.124
(7.6 +/- .4)LLL	(-19.2 +/- .7)LLL	(-4.7 +/- .3)LLL	(3.2 +/- .1)LLL	(1.25 +/- .06)LLL	(0.76 +/- .04) LLL	(0.43+/- .02)LLL	(63.73 +/- 1.6)LLL	(36.55 +/- 1.03)LLL	(33.76 +/- 1.32)LLL	(12.43 +/- 1.4)LLL	0.93 +/- 0.2	54.67 +/- 3.39	93.01 +/- 3.532
(7.3 +/- .2) RLL	(-18.6 +/- .5)RLL	(-4.5 +/- .2)RLL	(3.0 +/- .1)RLL	(1.23 +/- .04)RLL	(0.80 +/- .03)RLL	(0.43 +/- .03)RLL	(64.56 +/- 1.7)RLL	(36.43 +/- 1.11)RLL	(34.46 +/- 1.43)RLL	(13.24 +/- 1.16)RLL	0.94 +/- 0.3	55.62 +/- 4.39	94.14 +/- 3.41
(8.2 +/- .2)LLL	(-19.2 +/- .7)LLL	(-5.3 +/- .4)LLL	(2.84 +/- .1)LLL	(1.26 +/- .01)LLL	(0.77 +/- .01)LLL	(0.42 +/- .02)LLL	(65.42 +/- 1.9)LLL	(35.34 +/- 1.09)LLL	(35.33 +/- 1.32)LLL	(12.23 +/- 1.13)LLL	0.93 +/- 0.4	53.36 +/- 3.43	95.13 +/- 2.14
(6.9 +/- .5) RLL	(-17.4 +/- .9)RLL	(-5.2 +/- .2)RLL	(3.3 +/- .1)RLL	(1.22 +/- .02)RLL	(0.76 +/- .02)RLL	(0.41 +/- .03)RLL	(63.42 +/- 1.8)RLL	(35.32 +/- 2.1)RLL	(34.35 +/- 1.26)RLL	(12.13 +/- 1.32)RLL	0.94 +/- 0.3	54.33 +/- 4.21	94.31 +/- 3.21

POST-OPERATIVE GAIT ANALYSIS														
STANDING ANGLES				ALL TEMPORAL PARAMETERS										
KNEE VALGUS VARUS IN DEGREES	KNEE ROTATION IN DEGREES	KNEE FLEXION-EXTENSION IN DEGREES	ANKLE DORSAL-PLANTAR ROTATION IN DEGREES	STRIDE TIME(SEC)	STANCE TIME (SEC)	SWING TIME (SEC)	STANCE PHASE (%)	SWING PHASE (%)	SINGLE SUPPORT PHASE (%)	DOUBLE SUPPORT PHASE (%)	MEAN VELOCITY (M/S)	MEAN VELOCITY (% HEIGHT/S)	CADENSE (STEPS/MIN)
NORMAL VALUE (0 +/- 5)	NORMAL VALUE (-10 +/- 5)	NORMAL VALUE (5 +/- 5)	NORMAL VALUE (0 +/- 5)	NORMAL VALUE (1.1 +/- .09)	NORMAL VALUE (0.65 +/- .07)	NORMAL VALUE (0.44 +/- .05)	NORMAL VALUE (58.98 +/- 1.97)	NORMAL VALUE (40.03 +/- 3.56)	NORMAL VALUE (38.87 +/- 2.57)	NORMAL VALUE (10.27 +/- 3.09)	NORMAL VALUE (1.2 +/- .2)	NORMAL VALUE (80 +/- 5)	NORMAL VALUE (114 +/- 4.2)
(3.1 +/- .2)LLL	(-9.88 +/- .9)LLL	(5.5 +/- .2)LLL	(3.67 +/- .1)LLL	(1.25 +/- .03) LLL	(0.75 +/- .14) LLL	(0.45 +/- .02) LLL,	(63.26 +/- 2.61) LLL	(37.03 +/- 2.22) LLL	(36.32 +/- 1.2) LLL	(13.01 +/- 1.16) LLL	0.98 +/- 0 .1	59.21 +/- 5.14	96.61 +/- 4.331
(3.9 +/- .2) RLL	(-10.6 +/- .6)RLL	(4.6 +/- .3)RLL	(3.8 +/- .1)RLL	(1.26 +/- .02) RLL	(0.76 +/- .07) RLL	(0.43 +/- .03)RLL	(61.31 +/- 2.01)RLL	(39.55 +/- 1.93) RLL	(36.39 +/- 1.19) RLL	(14.46 +/- 2.1)RLL	0.99 +/- 0.1	51.36 +/- 3.13	95.22 +/- 4.99
(3.6 +/- .1) RLL	(-10.7 +/- .6)RLL	(4.3 +/- .3)RLL	(3.72 +/- .1)RLL	(1.26 +/- .02)RLL	(0.75 +/- .04) RLL	(0.44 +/- .03) RLL	(62.24 +/- 2.06) RLL	(38.33 +/- 1.20) RLL	(38.12 +/- 1.15) RLL	(14.98 +/- 1.6) RLL	0.97 +/- 0.1	57.54 +/- 3.34	96.57 +/- 5.296
(2.8 +/- .2)LLL	(-9.8 +/- .5)LLL	(6.2 +/- .2)LLL	(4.2 +/- .1)LLL	(1.25 +/- .04) LLL.	(0.72 +/- .07) LLL	(0.43 +/- .01)LLL	(61.31 +/- 1.32) LLL	(39.55 +/- 2.11) LLL	(34.22 +/- 1.13) LLL	(13.6 +/- 1.3) LLL	0.96 +/- 0.1	56.57 +/- 4.72	96.63 +/- 5.012
(3.9 +/- .2)LLL	(-10.6 +/-.8)LLL	(5.3 +/- .5)LLL	(3.6 +/- .1)LLL	(1.20 +/- .9)LLL	(0.74 +/- .06)LLL	(0.45 +/- .03)LLL	(62.12 +/- 3.26)LLL	(38.72 +/- 1.14)LLL	(35.23 +/- 1.15)LLL	(14.03 +/- 1.58)LLL	0.99 +/- 0.1	55.86 +/- 6.01	96.11 +/- 4.13
(3.8 +/- .4)LLL	(-9.8 +/- .7)LLL	(5.3 +/- .1)LLL	(4.3 +/- .1)LLL	(1.26 +/- .06) LLL.	(0.75 +/- .04) LLL	(0.47 +/- .02)LLL	(60.14 +/- 3.32) LLL	(41.98 +/- 1.69) LLL	(36.12 +/- 1.13) LLL	(13.6 +/- 1.6) LLL	0.97 +/- 0.1	56.44 +/- 4.43	99.34 +/- 4.136
(4.6 +/- .2)LLL	(-10.1 +/-.8)LLL	(5.7 +/- .1)LLL	(3.6 +/- .1)LLL	(1.22 +/- .06) LLL.	(0.75 +/- .05) LLL	(0.45 +/- .02)LLL	(62.26 +/- 1.25) LLL	(38.55 +/- 1.30) LLL	(35.12 +/- 1.19) LLL	(14.5 +/- 1.1) LLL	1.01 +/- 0.1	57.11 +/- 3.73	98..74 +/- 3.22
(4.8 +/- .2) RLL	(-10.5 +/- .6)RLL	(10.1 +/- .9)RLL	(3.7 +/- .1)RTT	(1.24 +/- .06) RLL	(0.75 +/- .04) RLL	(0.46 +/- .03) RLL	(60.34 +/- 1.35) RLL	(39.03 +/- 1.65) RLL	(36.56 +/- 1.22) RLL	(14.2 +/- 1.32) RLL	1.1 +/- 0.1	57.27 +/- 5.24	99.5 +/- 5.24
(3.9+/- .3)LLL	(-9.78 +/- .7)LLL	(5.5 +/- .1)LLL	(3.1 +/- .1)LLL	(1.24 +/- .03) LLL.	(0.73 +/- .06) LLL	(0.43 +/- .05)LLL	(63.38 +/- 2.16) LLL	(37.64 +/- 1.25) LLL	(36.1 +/-1.28) LLL	(15.4 +/- 1.03) LLL	1.03 +/- 0.1	57.23 +/- 3.53	97.033 +/- 5.12
(3.3+/- .2)LLL	(-10.2 +/- .7)LLL	(5.2 +/- .1)LLL	(4.1 +/- .1)LLL	(1.20 +/- .04)LLL	(0.72 +/- .05)LLL	(0.45 +/- .1)LLL	(62.15 +/- 23.32)LLL	(38.82 +/- 1.25)LLL	(35.32 +/- 2.37)LLL	(13.14 +/- 2.21)LLL	1.02 +/- 0.1	56.99 +/- 5.44	96.12 +/- 4.41
(3.9 +/- .3) RLL	(-9.76 +/- 1.6)RLL,	(5.6 +/- .7)RLL	(4.2 +/- .1)RTLL	(1.23 +/- .04)RLL	(0.73 +/- .03) RLL	(0.47 +/- .01) RLL	(62.35 +/- 1.32) RLL	(38.35 +/- 1.16) RLL	(37.92 +/- 1.18) RLL	(14.63 +/- 1.23) RLL	1.0 +/- 0.1	55.99 +/- 5.53	98.057 +/- 3.11
(4.2 +/- .1)LLL	(-10.3 +/- .7)LLL	(5.7 +/- .4)LLL	(3.9 +/- .1)LLL	(1.24 +/- .05)LLL	(0.75 +/- .05) LLL	(0.45+/- .01)LLL	(60.33 +/- 1.5)LLL	(41.55 +/- 1.22)LLL	(37.76 +/- 1.14)LLL	(13.42 +/- 1.41)LLL	0.99 +/- 0.2	53.67 +/- 4.39	97.01 +/- 6.17
(3.3 +/- .4) RLL	(-10.6 +/- .5)RLL	(6.5 +/- .2)RLL	(4.1 +/- .1)RLL	(1.22 +/- .05)RLL	(0.77 +/- .03)RLL	(0.46 +/- .04)RLL	(62.36 +/- 1.5)RLL	(38.43 +/- 1.32)RLL	(36.46 +/- 1.33)RLL	(14.24 +/- 1.15)RLL	0.96 +/- 0.3	54.62 +/- 4.19	99.14 +/- 4.13
(4.2 +/- .1)LLL	(-9.89 +/- .7)LLL	(4.3 +/- .4)LLL	(3.8 +/- .1)LLL	(1.25 +/- .02)LLL	(0.76 +/- .04)LLL	(0.44 +/- .03)LLL	(64.32 +/- 1.6)LLL	(36.34 +/- 1.29)LLL	(35.33 +/- 1.32)LLL	(14.23 +/- 1.16)LLL	0.99 +/- 0.4	54.36 +/- 3.13	98.13 +/- 5.16
(3.9 +/- .1) RLL	(-10.4 +/- .9)RLL	(5.2 +/- .2)RLL	(3.6 +/- .1)RLL	(1.20 +/- .01)RLL	(0.75 +/- .03)RLL	(0.43 +/- .02)RLL	(61.22 +/- 1.7)RLL	(39.12 +/- 1.6)RLL	(36.35 +/- 1.16)RLL	(15.03 +/- 1.12)RLL	0.99 +/- 0.3	53.33 +/- 4.12	98.11 +/- 4.11