Effect of the Ilizarov Bone Fixation on Gait Cycle and Its Parameters

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Abstract—This Walking is the first manner of displacement for human and essential for daily life activities. The human gait can be analyzed from several points of view and specialization. The Ilizarov frame is an external fixation device, primarily used for the treatment of complex fractures which adversely affects the functional state of the locomotor system. The objective of this paper was to analyses the spatiotemporal parameters of gait during treatment by the Ilizarov technique. Materials and methods: The study consists of 6 males with lower limb injuries performed walking trials, with and without the Ilizarov frame. Gait analysis was carried out using a camera and Kinovea application. Results: walking speed (p = 0.385), stride length (p =0.325), cadence (p = 0.641), stance time of operated limb (p = 0.265), swing time of operated limb (p = 0.959), double support time of operated limb (p=0.227) respectively were all no important difference with Ilizarov and without it. The times (stance, swing, and double support) (p=0.018) for non-operated limb have significantly different with Ilizarov.

Keywords—Ilizarov external, spatiotemporal parameters, gait analysis, operated limb, non-operated limb.

1 Introduction

Human walking is a much complex biomechanical process. A large number of searches have been carried out in the field of human walking[1, 2]. In the medical domain, the knowledgeable of human gait characteristics, the observation and estimating of spatial and temporal parameters of gait, and their changes provide useful therapeutic information for various musculoskeletal diseases [3]. Spatio-temporal parameters are also renowned as general gait parameters. They are answerable for providing the simplest way of objective gait valuation (gait specifications). The gait analysis method considers time-distance parameters such as step and stride length, step width, cadence, velocity, phases (stance and swing), and foot strike and toe-off events for spatiotemporal.

The stride length is the most remarkable and advantageous gait parameter for both the medical and computing fields [4]. The gait cycle or stride is predominately defined as the interval between initial contact of one foot with the ground and subsequently contact of the same foot. The gait cycle consists of two main phases: the stance phase and the swing phase. The stance phase is that part of the gait cycle when the foot is in contact with the ground, and usually represents about 62% of the total healthy adult walking gait cycle. The swing phase is defined as the interval when the foot no longer contacts the ground and the limb advances in making ready for subsequent foot contact. The swing phase occupies the residual 38% of the gait cycle [5]. The stance phase is furthermore divided into an initial double stance, followed by a period of single stance and then a final period of double stance. During a double stance, the weight is transport from one foot to the other. Through a single stance, the center of mass of the body passes above the foot in preparation for shifting to the other limb [6, 7]. The cycle time is the interval of a complete gait cycle, which is divided into stance time and swing time[8].

Gait analysis can be described as a domain of biomechanical engineering dealing with the subject of human motion. Via means of various measuring techniques obtainable (for example video registration), human gait data are captured, furthermore, analysis and computations are applied to obtain all the necessary data for valuing the quality of the subject's gait, involving basic gait parameters (stride length, cadence, velocity) [9-11].

In the past, patients with fractures that be unsuccessful in curing (non-union) or healed incorrectly (mal-union) had a few treatments available to them. The patients who required surgical removal of infected bone (osteomyelitis) or cancerous bone had no choice but to have an amputation of the operated limb. The treating of such orthopedic conditions was revolutionized by Dr. Gavril Ilizarov, the Ilizarov frame takes its name from Dr. Gavril Abramovich Ilizarov [12]. The Ilizarov framework consists of individual elements that can be assembled into an unrestrained number of configurations. The adjustability of the apparatus permits the domination of bone angulation, rotation, translation, and lengthening or compression at one or further levels of a bone, either simultaneously or consecutively [13]. The Ilizarov external fixator provides good stabilization of the elongated segment of the locomotor system [14, 15]. During Ilizarov treatment, patients have to learn and adopt correct movement patterns, which requires a very long time since locomotor automatism is established after many repetitions of the correct movements[16, 17]. This study aims to state the effect of Ilizarov on general gait parameters.

2 Patients and Methodology

2.1 Patients

The research group consisted of 8 patients, of whom 6 males were undergone final analysis, treated by the Ilizarov method due to different injuries in the lower limb caused by accident war, as shown in table.1. Most of the patients had subject surgeries

with other techniques before Ilizarov's operation, but without improvement. Therefore, the Ilizarov method was used for treating them.

Table 1. Characteristic of patient participation

Patient No.	sex	age	Type of injury (Etiology)
1	male	32	6-cm long bone loss in the mid-diaphyseal (tibial bone loss)/ Post-traumatic
2	male	27	fracture of the bottom of the leg bone resulting in severe pain and limited ankle movement.
3	male	28	multiple fractures (above ankle and in femur bone)
4	male	24	mid-diaphyseal of tibia fracture
5	male	50	Deformity of shank bone
6	male	33	Deformity of shank bone

2.2 Methods

Parameters used in gait analysis and related to time and space are known as temporal and spatial parameters, respectively. These parameters include cadence (stride frequency), stride length, and walking speed. There are several techniques used to measure gait parameters. The procedure is shown below permits each of the three general gait parameters to be measure simultaneously via monitoring the registered gait of the patients by video. The patient completed two test conditions (without Ilizarov (WOI) and with Ilizarov (WI)) at a self-selected, comfortable walking speed bypassing two landmarks in the recording whose positions are known. Spaces before the first mark and after the second marker are essential for acceleration and slowing down during normal walking. When the recording is completed, the period taken to cover the distance between markers is measured, and the number of steps taken is counted. Both of the distance and the time mention previously were measure by utilizing the Kinovea application, as seen in Fig.1. Finally, the time, the distance and the number of steps are all known; general gait parameters may be calculated by use of the following formula [8]:

$$\text{Cadence (steps/min)} = \text{steps counted} \times (60/\text{time (s)}) \tag{1}$$

$$\text{Stride length (m)} = \text{distance (m)} \times (2/\text{steps counted}) \tag{2}$$

$$\text{Speed (m/s)} = \text{distance (m)} / \text{time (s)} \tag{3}$$

Fig.1.   Kenova application. A=the patient, B= account the time, C= the distance of walking.

The stance and swing times for each participant subject were measured manually from the video recording by counting the frames in which the stance and swing take place and then dividing them by the camera's frame rate (25 frames/sec). Also knowing the stance and swing duration, the double support can be calculated via utilize of the following formula[18]:

$$\text{Total double support time (DS)} = \text{Stance} - \text{Swing} \tag{4}$$

3   Statistical Analysis

Statistical analysis was implemented using the IBM SPSS (Statistical Packages for Social Sciences) software version 21.0. Walking speed, cadence, stride length, stance time, swing time, and double support duration data sets were found to be normally distributed through Shapiro–Wilk and Kolmogorov–Smirnov tests ($P \leq 0.05$). Descriptive statistics were completed for data sets (means and SDs). Paired- samples T-test used to compare mean values of the variable "difference between without Ilizarov (WOI) and with Ilizarov (WI)". Each analysis was carried out at the level of importance set at a p-value <0.05 was considered as significant discrimination point.

4   Results

From table.2: mean walking speed, cadence and stride length were higher and not significantly different for WOI compared to WI, where (WOI=0.303 ms^{-1}(SD 0.114); WI=0.258 ms^{-1} (SD 0.183)), (WOI=52.828 steps.min^{-1}(SD 11.353); WI=50.104 steps.min^{-1}(SD 16.869)), and (WOI=0.636m (SD 0.291); WI=0.583m (SD 0.258)) (P≥

0.05) respectively. The mean stance and swing times of operated limb increased when patient wearing Ilizarov frame (WIO=53.963 (SD 28.631); WI=70.301 (SD 8.767)) and (WOI=29.371 (SD 18.108); WI=29.698 (SD 8.767)), but differences between WOI and WI were no statistically significant (P≥ 0.05) (table.3). The mean stance time of non-operated limb increased when the patient wearing the Ilizarov frame (WOI=73.877 (SD 9.789); WI=78.161 (SD 11.417)), and there was statistically significant between WOI and WI (p≤0.05) (table.3). While the mean swing time of non-operated limb decreased when the patient wearing the Ilizarov frame (WOI=26.123 (SD 9.789); WI=21.839 (SD 11.417)), and also there was statistically significant between WOI and WI (p≤0.05) (table.3). The mean double support duration of operated limb and non-operated limb increased when patient wearing Ilizarov frame (WOI=24.59 (SD 25.072); WI=40.603 (SD 17.534)) and (WOI=47.733 (SD 19.577); WI=56.323 (SD 22.833)); but there was not statistically significant between WOI and WI for operated limb (P≥ 0.05), either non-operated limb has statistically significant between WOI and WI (p≤0.05) (table.4).

5   Discussion

This study was focus on comparing significant differences for temporospatial variables between wearing the Ilizarov frame and without. The walking speed of WI (0.258 ms^{-1}) was slower than walking speed of WOI (0.303 ms^{-1}) and no significant difference between them. Layton R. B.et al found the walking speed for healthy subjects was decreased with the Ilizarov apparatus also, but they found a significant difference between with and without Ilizarov[19]. In our study, the absence of an important difference for walking speed can be attributed to the deformity of the lower limb for patients. The patients needed more time for walking when wearing the apparatus; therefore, the cadence of WOI (52.828 steps.min^{-1}) was higher and not significantly different compared to the cadence of WI (50.104 steps.min^{-1}). The presented study revealed that stride length no significant differences between test conditions. Also, Layton R. B.et al found no significant difference between with and without Ilizarov[19]. Several reports in the past have shown a significantly reduced stride length when treated with an external fixator [20], increased asymmetry between limbs when wearing a unilateral ankle weight [21], and an increased risk of tripping when stepping over obstacles while wearing heavy-duty boots [22]. The study shows that the stance and swing times on operated limbs were longer WI compared to WOI, and no significant difference between them. The stance time on the non-operated limb is increased and considerable difference with Ilizarov, but the swing time on the non-operated limb is a deceased and significant difference with Ilizarov. From mean values in a table.3, it is observed for both tests (WOI and WI) that stance time on the operated limb was shorter than stance time on the non-operated limb, while swing time on the operated limb was longer than swing time on the non-operated limb. This means the patients depend (leaning) on a non-operated limb more than operated limb to compensate asymmetry of gait. Previous literature identified the stance phase in the operated on the limb was shorter than in the non-operated on the limb, whilst the swing phase in the operated on the limb was longer than in the non-operated on the limb in children with leg length discrepancy [23, 24]. Also, the study

demonstrated that the double support duration of the operated limb with Ilizarov was higher and no significant difference compared to without Ilizarov, whilst the double support duration of the non-operated limb with Ilizarov was a higher and significant difference compared to without Ilizarov. i.e., the Ilizarov device effects on non-operated to support and stabilize the lower limb during gait.

Table 2. Statistical analysis of gait parameters

Gait parameters	Lower extremity	Mean ± SD	t	p
Walking speed (m/s)	Without Ilizarov	0.303 ± 0.114	0.952	0.385
	With Ilizarrov	0.258 ± 0.183		
Cadence (steps/min)	Without Ilizarov	52.828 ± 11.353	0.495	0.641
	With Ilizarov	50.104 ± 16.869		
Stride length (m)	Without Ilizarov	0.636 ± 0.291	1.09	0.325
	With Ilizarrov	0.583 ± 0.258		

Table 3. Statistical analysis of stance and swing phase expressed as a percentage of the total gait

	Operated Limb	Mean±SD	t	p	Non-operated limb	Mean ± SD	t	p
% Stance time	Without Ilizarov	53.963 ± 28.631	-1.255	0.265	Without Ilizarov	73.877 ± 9.789	-3.454	0.018
	With Ilizarov	70.301 ± 8.767			With Ilizarov	78.161 ±11.417		
% Swing time	Without Ilizarov	29.371 ± 18.108	-0.054	0.959	Without Ilizarov	26.123 ± 9.789	3.455	0.018
	With Ilizarov	29.698 ± 8.767			With Ilizarov	21.839 ±11.417		

Table 4. Statistical analysis of double support duration expressed as a percentage of the total gait

	Operated Limb	Mean ± SD	t	p	Non-operated limb	Mean ± SD	t	p
%Double support duration	Without Ilizarov	24.59 ± 25.072	-1.377	0.227	Without Ilizarov	47.733 ±19.577	-3.456	0.018
	With Ilizarrov	40.603 ±17.534			With Ilizarrov	56.323 ±22.833		

6   Conclusion

This review identified that the presence or absence of the Ilizarov device does not significantly affect on gait parameters (speed, cadence, and stride length), and times (stance, swing and double support) for operated limb. Whereas the Ilizarov influences on times (stance, swing, and double support) for non-operated limb.

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