Model and Statistical Analysis of Fracture Healing by Electric Stimulation

Kumaravel. S, Theerthagiri. P. R, Sundaram. S
PRIST University
Thanjavur-613403, Tamilnadu, India

ABSTRACT: *The healing of fractures can be monitored using electrical current across the wound. Over a period of seven years, 32 fracture patients, group 1 comprising of 20 patients and group 2 of 12 patients were studied. Group 1 was electrically stimulated while group 2 was not electrically stimulated. The process of healing was monitored as current versus number of days. The current stabilized after the union of fracture. The data was subjected to regression analysis and fitted to a FOPDT model with an error of less than 5%. An ANOVA analysis of the two groups indicated an F ratio which suggested that results are significant.*

Keywords: Healing Fracture, ANOVA Analysis, FOPDT Modeling

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1. Introduction

The country is facing ever increasing road accidents due to an exponential increase in two wheelers traffic sharing the same road with heavier vehicle. The resultant fractures range from simple hair line cracks to complicated breakages with loss of bone materials. Researchers have used electrical signal in animals to speed up healing and also monitor fracture healing (1-6). This work is an application of the above work to human beings from a diagnostic aspect. Research on 20 patients (Group 1) with electrical stimulation and 12 almost similar (Group 2) without electrical stimulation were studied and reported by us (7-11). The work conclusively suggested that healing of fractures can be diagnosed faster and safer with electrical current.

1.1 Experimental Set Up

The setup has been published earlier (9). However a typical case is included here in Figure-1 (a to e) as a representative case. The voltage and current was decided by a number of trials and used on patients after institutional ethical committee clearance.

1.2 Results & Conclusions

The current versus number of days for four patients are shown (figure 2). The resultswere smoothened out because the patients with sensors on them do move during the recordings.

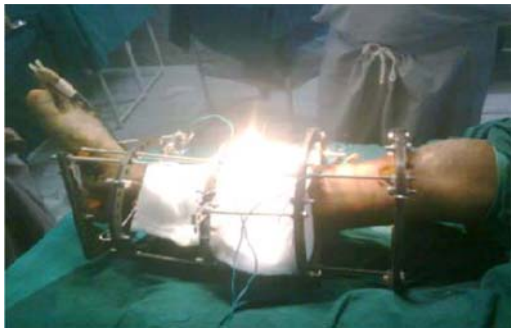
The experimental data was fitted to a First order plus dead time (FOPDT) model equations 1 and 2,

$$I = I_O + K\,[(1 - e^{t/\tau})] \quad t < \delta \tag{1}$$

$$I = I_O + K\,[(1 - e^{t/\tau})]\,(1 - e^{t-\delta/\tau})\,] \quad t > \delta \tag{2}$$

a) Preoperative of X-ray

b) After provisional external fixator



c) Intra operative photograph typical case of fracture healing

d) Post operative X-rays of a typical case

e) The X-rays of the patient after removal of the rings and the patient standing without the support

Figure 1. (a to e) Case study of a typical fracture

where

I - Current, mA

I_O - Initial Current, mA

K - Gain

t - Time, days

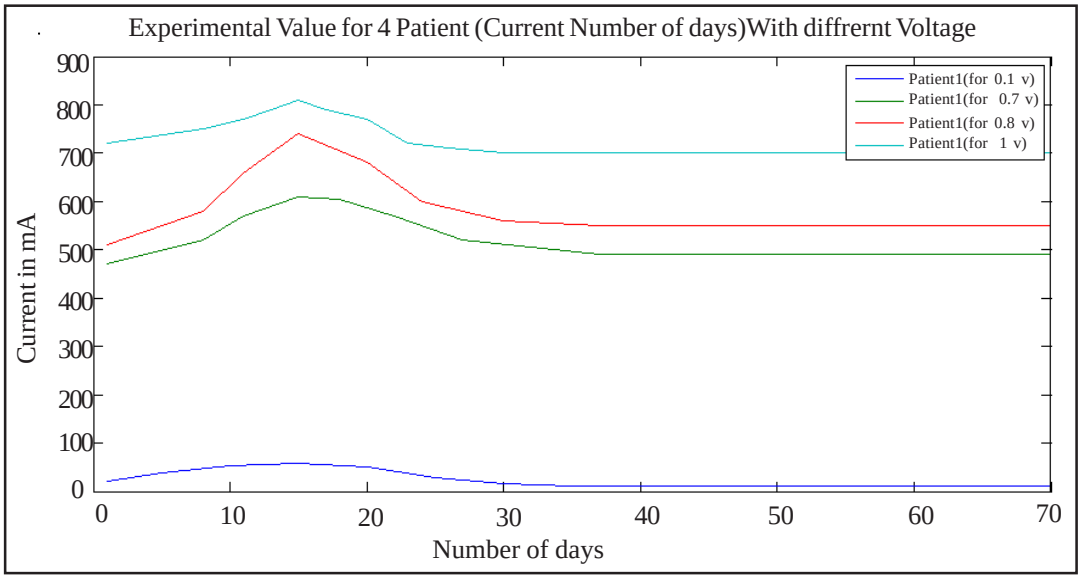


Figure 2. Experimental values for 4 patients

S.no	Group-1: Electric Stimulation		Group-2: Non Electric Stimulation	
	No of X-rays	Days in ring	No of Xrays	Days in ring
1	11	70	26	227
2	10	158	30	250
3	8	133	50	287
4	34	241	32	358
5	20	143	36	240
6	8	117	30	160
7	12	133	16	178
8	6	98	22	254
9	12	120	32	337
10	4	127	24	370
11	10	184	17	282
12	6	84	12	262
13	6	59	-	-
14	4	59	-	-
15	3	38	-	-
16	4	50	-	-
17	5	105	-	-
18	6	97	-	-
19	6	102	-	-
20	4	110	-	-

Table 1. Comparison of groups 1 and 2

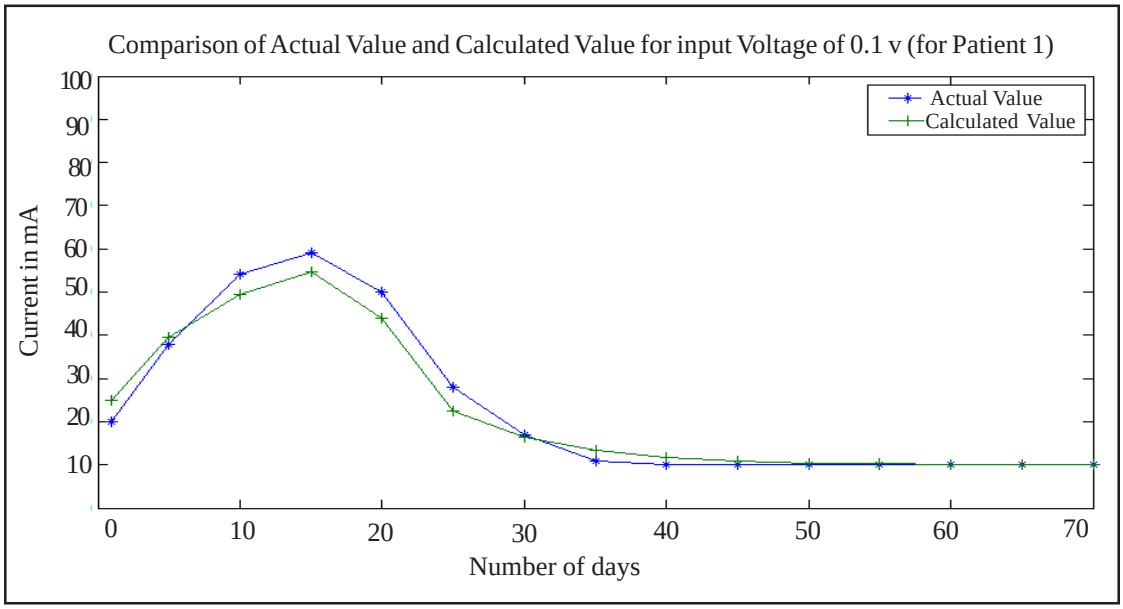


Figure 3. Comparison of experimental value and calculated value for patient 1

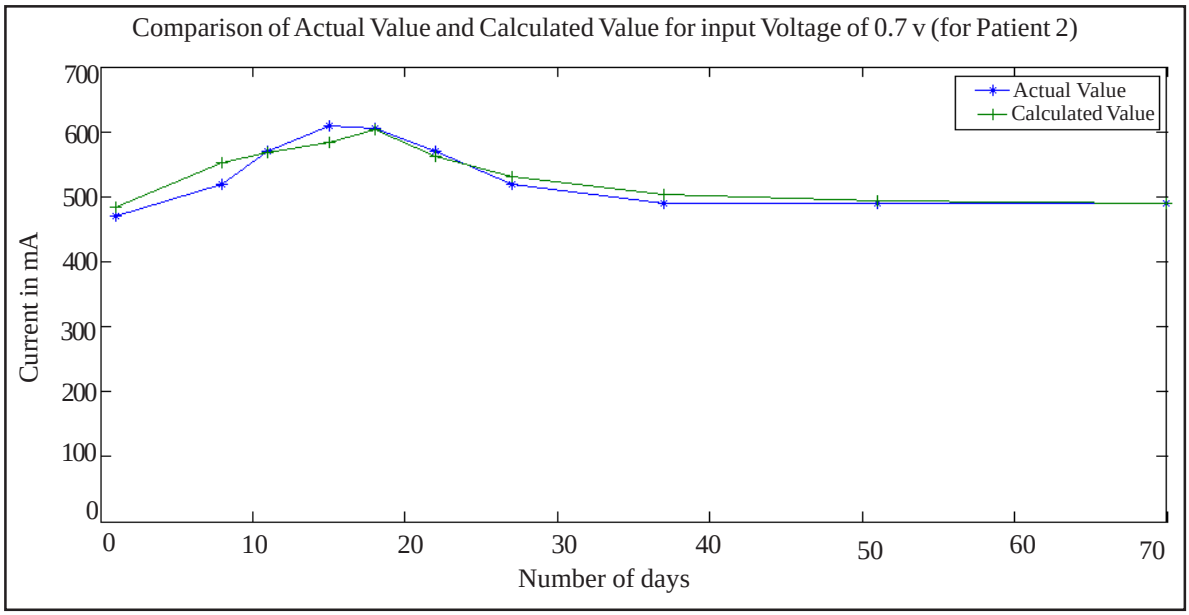


Figure 4. Comparison of experimental value and calculated value for patient 2

τ - Time constant, days

δ - Pulse width, days

The experimental and calculated values are shown in figures (3-6). The model fitted the experimental data with an error of less than 5%.

An ANOVA analysis (12) of group 1 and group 2 based on the number of x-rays and duration of healing was made. Table 1 compares the number of x-rays and duration in Ilizarov rings for the groups 1 and 2. Table 1 clearly indicates that electrical stimulation decreases the number of x-rays and duration for healing.. An ANOVA analysis of both groups on duration and number of x-rays was studied. F ratio for 5% confidence level for number of x-rays was 27.29 and for the duration 19.3. Referring

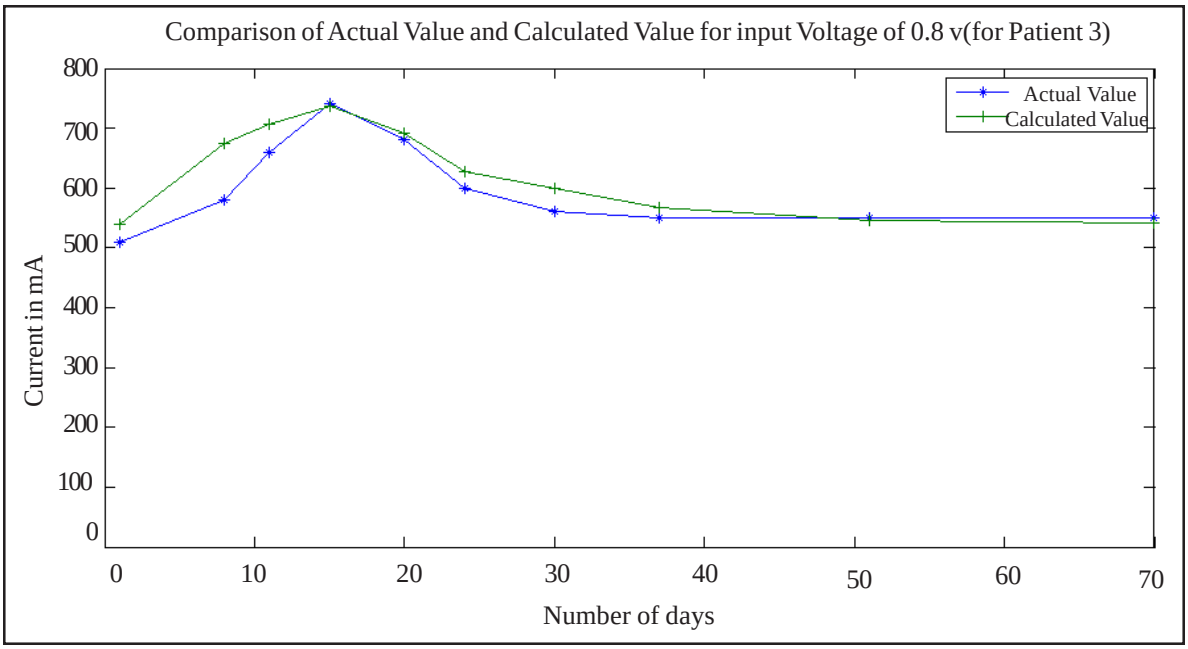


Figure 5. Comparison of experimental value and calculated value for patient 3

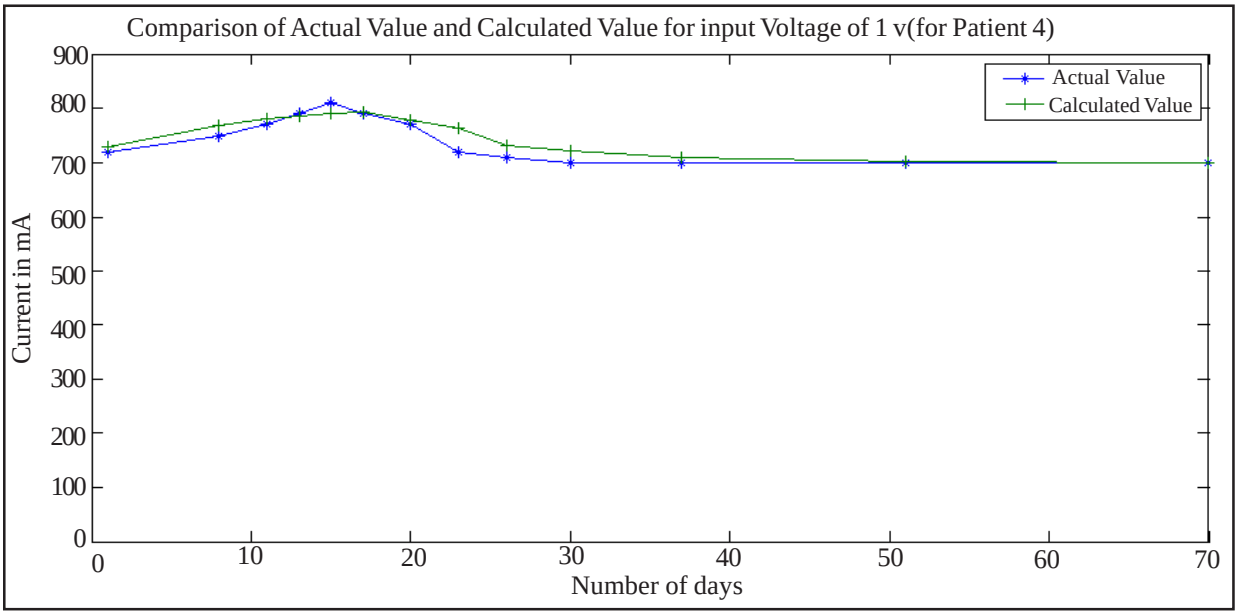


Figure 6. Comparison of experimental value and calculated value for patient 4

to standard ANOVA tables (12) indicates that the difference between group 1 and group 2 is significant and not by chance. Further work with more number of patients is in progress.

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