# Method for Automated Bone Shape Correction within Bone Distraction Procedure

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**Abstract.** The method for automated bone shape correction within bone distraction procedure is presented. High precision deformation angle measurement is provided by the software for X-Ray images processing. Special BDC v.1.0.1. application is designed. The purpose of the BDC is modeling of the bone geometry structure to calculate the appropriate distraction forces. The correction procedure control is realized by the hardware of the distraction system.

## 1. Introduction

Bone distraction and compression osteogenesis (DCO) is an effective orthopedics procedure to heal both inborn and acquired injures of the human musculoskeletal system. The history of the DCO started at the beginning of 20th century when an Italian surgeon, Alessandro Codivilla, performed the first bone lengthening procedure [1]. However, the Ilizarov system, developed in 1950s, became a leader in clinical practice. According to G.A. Ilizarov, the bone distraction rhythm is be more than 60 distraction steps per day to obtain the natural bone growth temp [2]. This rhythm is provided by automated bone lengthening systems with adjusted distraction force values [3].

Apart from the linear bone lengthening issues, there are other groups of injuries related to bone shape deformation. They are marked out as varus and valgus deformations (figure 1 [4]). The causes of these injuries are childhood diseases (e.g. rachitis, metabolic disorders, etc.), teenage diseases (e.g. Ca and vitamin D deficiency, excessive limb load, etc.), adult diseases (e.g. traumas and joint pathology processes).

The conventional method for bone deformation correction is distraction osteogenesis (DO). Further, the studies [5,6] provide the advantages of continuous DO for bone regeneration acceleration. For complex deformations, surgical methods are applied. Increased painfulness for patients and a subjective component within the distraction force adjustment are major shortcomings of the bone shape correction procedure.

The new bone shape correction method was designed to eliminate the existing drawbacks. It is based on the limb X-Ray image processing to create a bone geometry model. According to this model, the special software will provide the total control of the bone correction procedure.

 

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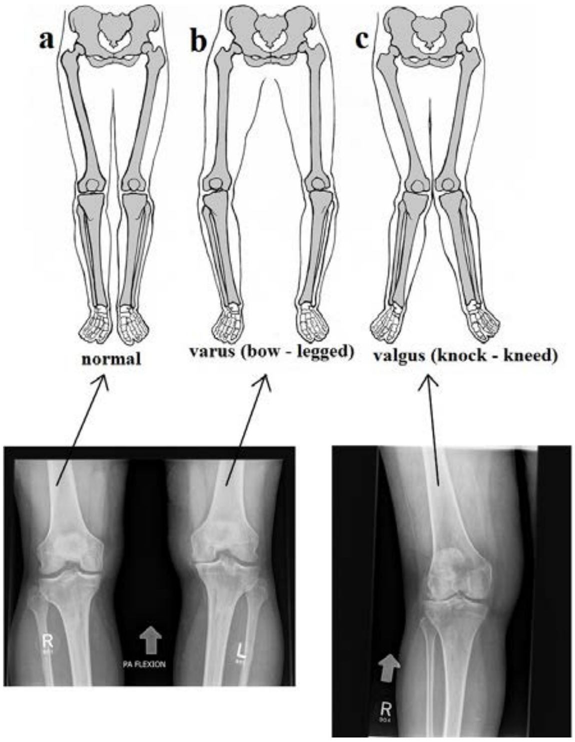


**Figure 1.** The images show a normal knee alignment (a), varus (bowed legs) (b) and valgus (knock knee) (c) alignment.

## 2. Materials and methods

Modern X-Ray procession techniques provide high-precision determination of the bone deformation angle. The investigation was performed using the Agfa NX v. 8800 SU1 software for digital X-Ray images processing. We identified the deformation angle for 10 patients from the Emergency Hospital in Tomsk, Russia. Figure 2 shows an NX image of one of the patients. The built-in instruments of this software are able to determine and process the region of interests.


**Figure 2.** The Agfa NX v. 8800 SU1 software with pelvic limb X-Ray image.

Before the geometry model design, we set the external fixation system ring diameter *l* equal to 160 mm and the threaded nail length *r* equal to 200 mm to simplify further calculations. The example of the bone geometry model is shown in figure 3. The main issue is to identify the deformation value of *x*. After that, the appropriate gain to decrease the deformation can be set. For distraction force setup and calculation of the variable *x*, a special software BDC (Bone Distraction Control) v. 1.0.1 was designed.

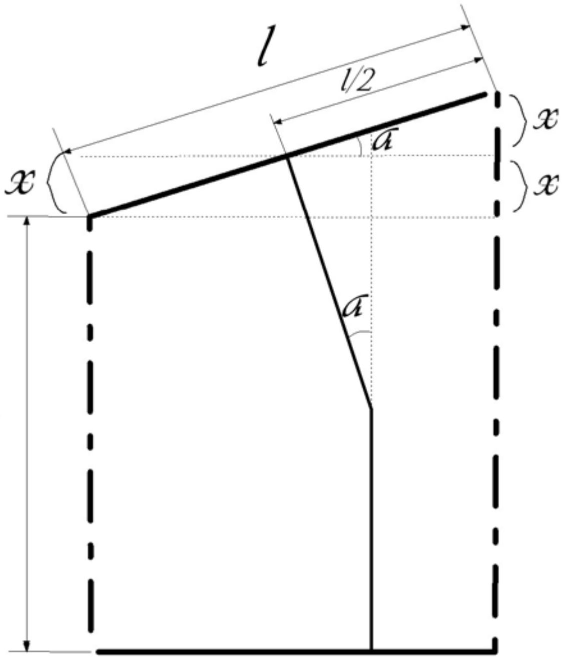


**Figure 3.** Defected bone geometry model.

## 3. Results

As can be seen in figure 3, the defected bone is fastened in the upper ring center (point *l/2*). The variable *x* represents the difference between the upper ring horizontal axis and the actual ring position. The algorithm to determine the motor output force value is as follows:

1. The deformation angle is measured with NX software;
2. The *X* value is calculated by BDC v.1.0.1. software;
3. The *ratio* between the motor ganes is defined.
4. In compliance with this ratio, the output motor force is set.

The *X* and *ratio* values are calculated by the formulas:

$$x = \frac{l \cdot \sin(\alpha)}{2} \tag{1}$$

$$ratio = \frac{r + 2x}{2} \tag{2}$$

The basic motor gain value is set as 50% of the maximum motor power level. For example, if ratio=1.3, then the first motor gain level is 50%, and the second one is 65% $(50 \cdot 1.3)$. The system model is shown in figure 4, where G1 and G2 are the output gains of the motors.

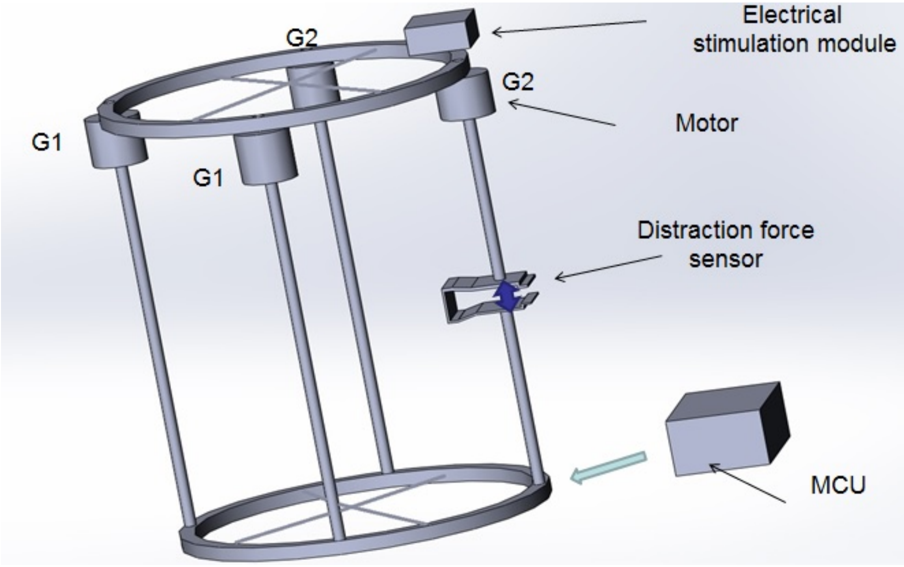


**Figure 4.** 3D model of distraction system for limb correction.

Software BDC v.1.0.1. was created on the basis of the IDE Qt v. 4.8.4. The main window screenshot is shown in figure 5. The measured deformation angle value is set in the field "Angle" of the software. The gains of the motors are set in accordance with the calculated ratio value. Communication with hardware is realized via the Bluetooth interface.

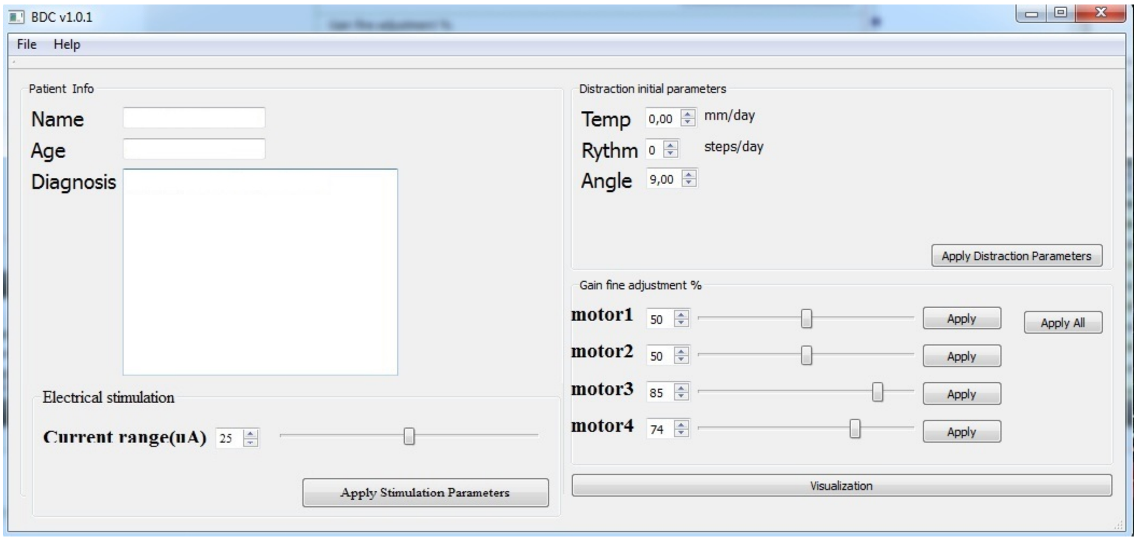


**Figure 5.** BDC v.1.0.1. main window.

## 4. Conclusion
The designed method provides opportunities for remote control of the bone shape correction. The major advantage of the method is high precision deformation angle calculation and automatic deformation removal. The physician is able to adjust the motor gain parameters to adapt the method for an individual patient.

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