



Gradual correction of nail deformity with adjustable tension: a new technique using steel wire and elastic components

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Abstract

Introduction Nail deformity is a common condition in podiatry, affecting 15–20 % of the population at different stages of their life. The disorder can cause chronic pain with a greater risk of infectious complications and significant limitations in activities of daily living. Minimally invasive and affordable solutions are needed for the problem. The key difference between the technique proposed and similar approaches lies in a rigid wire to be replaced with elastic components to allow adjustable gradual nail tensioning and stable fixation.

The **objective** was to determine the effectiveness of a minimally invasive technique using a steel wire combined with elements of elastic orthodontic chains made of medical polyurethane (elastofors) or nickel-titanium metal alloy in the form of nitinol springs to provide adjustable gradual tension for nail deformity correction.

Material and methods The method suggests creating customized corrective systems based on a steel wire and a selected active element. The systems are secured to the nail with hooks, ensuring constant, controlled tension. The study included patients with various types of nail deformities, excluding those with acute inflammatory processes. Standard onychoxia instruments and elastic elements (Elastofors and nickel-titanium springs) were used. Results were assessed by measuring the nail width and tension force every two weeks for two months.

Results and discussion The technique demonstrated high efficacy in correcting different types of nail deformities, with the nail width increasing from 2 mm to 4.1 mm over eight weeks. The technique is minimally invasive and causes no discomfort to patients. Elastic elements provide a gentle and comfortable pressure on the nail without affecting the patient's ability to function or perform daily activities. The technique is universal and applicable to different types of deformities. Prospects for further research might include introduction of adhesive platforms for uniform pressure distribution; the study of alternative alloys (titanium-molybdenum, cobalt-chromium) and optimization of wire-free Elastofors fixation.

Conclusion The technique was shown to be effective in the nail deformity correction, combining minimal invasiveness, adaptability and aesthetics. The results offer potential for implementation in clinical practice with an emphasis on personalized treatment.

Keywords: onychoxia, nail deformity, ingrown toenail, correction systems, podology, Elastoforce, nitinol

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INTRODUCTION

Deformity of the nail plate including onychocryptosis, onychogryphosis and transverse/longitudinal curvature are among most common pathologies in podiatry, affecting 15-20 % of the population at different periods of life [1]. The disorder can cause chronic pain with a greater risk of infectious complications and significant limitations in activities of daily living [2]. In addition to a variety of conservative treatments for correcting ingrown nails (tamponade, orthonyxia with staples) and surgical techniques (resection with matrix phenolization), there are minimally invasive and affordable solutions [2, 3]. This is due to the high recurrence rate (up to 70 % with conservative treatment) and postoperative complications [3].

Orthonyxia, a non-surgical correction of nail deformities is a promising method with use of mechanical systems. Correction of ingrown nails using metal braces dates back to the mid-20th century. One brace that has maintained its significance since the 1940s is the Ross-Fraser brace. However, documentary evidence of the authorship and date of creation is limited, as patent records and publications from that period do not contain direct references to Ross Fraser. Modern sources often attribute popularization of the method to the work of podiatrists in the 1960^s and 1970^s. Modern techniques, such as 3TO (three-component point orthonyxia), are based on a combination of support elements and wires to create targeted tension [4].

The key difference between the technique proposed and similar approaches lies in a rigid wire to be replaced with elastic components to allow adjustable gradual nail tensioning and stable fixation.

The **objective** was to determine the effectiveness of a minimally invasive technique using a steel wire combined with elements of elastic orthodontic chains made of medical polyurethane (elastofors) or nickel-titanium metal alloy in the form of nitinol springs to provide adjustable gradual tension for nail deformity correction.

MATERIAL AND METHODS

The study included six female patients aged 40 to 60 years, with deformity of the nail plate and a degree of ingrowth no higher than the Mozena grade I [5].

Inclusion criteria included presence of nail plate curvatures, absence of contraindications to orthonyxia.

Exclusion criteria included acute inflammatory processes in the nail bed (paronychia, felon), active onychomycosis, systemic diseases (e.g., diabetes mellitus with signs of diabetic foot).

All patients were informed about the objectives and methods of the study and gave written consent for publication of the results.

Tools and materials used

- Steel wire with a diameter of 0.4 mm as the basic fixing element to ensure the construct stability;
- Wire working tools:
 - wire cutters for cutting and adjusting a length;
 - round-nose pliers for loops and bends;
 - needle holder for precise installation of elements;
- Adhesive materials:
 - adhesive — to prepare the surface of the nail plate prior to applying the composite;

- light-curing viscous flow composite for fixation of active elements;
 - polymerization lamp (wavelength 420–480 nm) for composite activation;
- Preparing the nail plate:
- pedicure clippers;
 - diamond-coated cutter.

Active element

Elastofors (chain) and closed springs made of nickel-titanium alloy were active elements used with the method. The materials were chosen due to their proven effectiveness in orthodontics and availability [6, 7, 8]. The parameters selected for the springs were the diameter of 0.3556 mm (0.014 in), length varied from 3 to 4 mm depending on the individual needs of the patient.

The use of elastic elements ensured a smooth and controlled effect on the nail plate, minimizing the risk of trauma and overcorrection. A podiatrist selected the specific type of active element based on the individual nail deformity and the correction force required.

Attachment principle Both corrective systems are attached to the lateral edges of the nail plate using hooks made of steel wire. The design ensures even load distribution at the attachment points due to the symmetrical arrangement of the elements and the use of elastic elements.

The principle of corrective action Correction is achieved through the combined action of a lever and an elastic element. The lever mechanism, created by a curved wire, enhances the targeted action, while the elastic component (Elastofors/Nitinol spring) provides gradual and adaptive tension as the nail plate changes.

The principle of controlled force on the nail plate before the corrective system is placed The force applied to the nail plate can be adjusted by the podiatrist during installation of the corrective system through controlled tensioning of the flexible elements. Tensioning force can be measured using a dental dynamometer.

Placement of correction system

Steel wire forming two hooks was used to create the corrective system. The hooks were secured under the nail plate on both sides, with the wire length and bending angle adjusted to create a lever mechanism. At the point of force application, an additional link was formed on each wire to securely attach the active element (Fig. 1). The free ends of the wire were minimized to prevent excessive tension and possible damage to the nail plate during the application of the active element.

The elastofors tension force was adjusted by selecting the required number of chain links and using multiple layers of elastofors to achieve the desired tension force with a short active element length. For the springs, the tension force was adjusted by varying the length, diameter, and the tension force applied during the placement. Maintaining a balance was crucial: excessive tension could have led to reverse deformity of the nail or its separation from the nail bed.

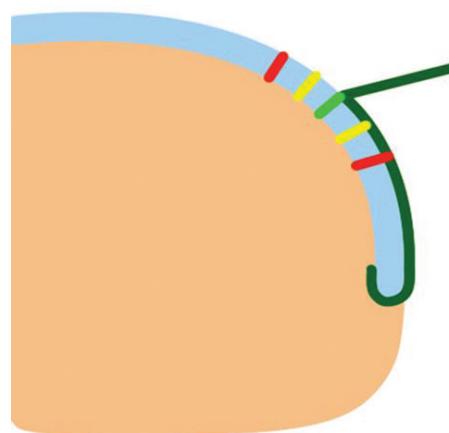


Fig. 1 A diagram showing the points of optimal force applied with a steel hook being placed

The junction between the active element and the steel wire was secured with a small amount of light-curing composite material to ensure the stability of the construct. The protruding wire elements were carefully trimmed and sanded to improve patient comfort. The complete installation of one corrective system, including nail plate preparation, took an average of 15 minutes. It is recommended to inspect and reinstall the system every four weeks to monitor the effectiveness of the correction and make any necessary adjustments.

Tensile force was measured from the first fixation point of the active element to the second using a dental dynamometer. Since the instrument readings are expressed in grams, the obtained values were converted to newtons using the formula $F = m \cdot g$, where m is the mass in kilograms ($1 \text{ g} = 0.001 \text{ kg}$) and g is the acceleration due to gravity ($\approx 9.81 \text{ m/s}^2$). Nail plate width was measured from ridge to ridge using a caliper with an electronic display.

RESULTS

Treatment results were assessed every two weeks after the installation of the corrective systems (Table 1). The corrective system was replaced with a new one every four weeks.

Table 1

Dynamics of changes in nail plate width and correction parameters

Patient	Toe	Nail width, mm					Active element		Tensile force, N	
		baseline	2 weeks	4 weeks	6 weeks	8 weeks	baseline	2 weeks	baseline	2 weeks
No. 1	Left first	15	16	16	17	17	Spring 0.014 inch 3 mm	Spring 0.014 inch 3 mm	3.434	3.434
	Right first	14	15.5	15.5	16	16	Spring 0.014 inch 3 mm	Spring 0.014 inch 3 mm	2.943	4.415
No. 2	Left first	14	15.5	15.5	16.5	17	Elastofors, two layers, two cells	Elastofors, two layers, two cells	1.962	2.943
No. 3	Left first	14	17	17	18.1	18.1	Spring 0.014 inch 3 mm	Elastofors, one layer, two cells	3.924	2.943
No. 4	Left first	15.5	17.9	18	19.5	19.5	Spring 0.014 inch 4 mm	Spring 0.014 inch 3 mm	4.905	4.905
	Right first	16	17.5	17.6	19	19	Spring 0.014 inch 3 mm	Elastofors, two layers, two cells	3.924	2.453
No. 5	Left first	14	14.5	14.5	16	16	Spring 0.014 inch 4 mm	Spring 0.014 inch 3 mm	4.415	4.905
	Right first	14,5	15	15	16	16	Titanium thread 0.014 inch	Titanium thread 0.014 inch		
No. 6	Left first	14	15	15	17	17	Elastofors, two layers, two cells	Elastofors, two layers, two cells	3.924	3.434
	Right first	13	14.5	14.5	16.8	16.9	Elastofors, three layers, two cells	Elastofors, two layers, two cells	2.453	3.434

For patient No. 5, Ni-Ti wire was used on the right first toe as part of a control protocol for dynamics in nail plate correction compared to the standard Ni-Ti wire correction technique. Tension was not recorded.

Dynamics in correction

All patients experienced an increase in nail plate width from 1.5 to 4.1 mm over two months, which was associated with deformity correction and restoration of the physiological shape.

Better improvement was observed in patients using nitinol springs (patients No. 1, No. 3, and No. 4), with a width increased to 4.5 mm (Figs. 2, 3, 4).

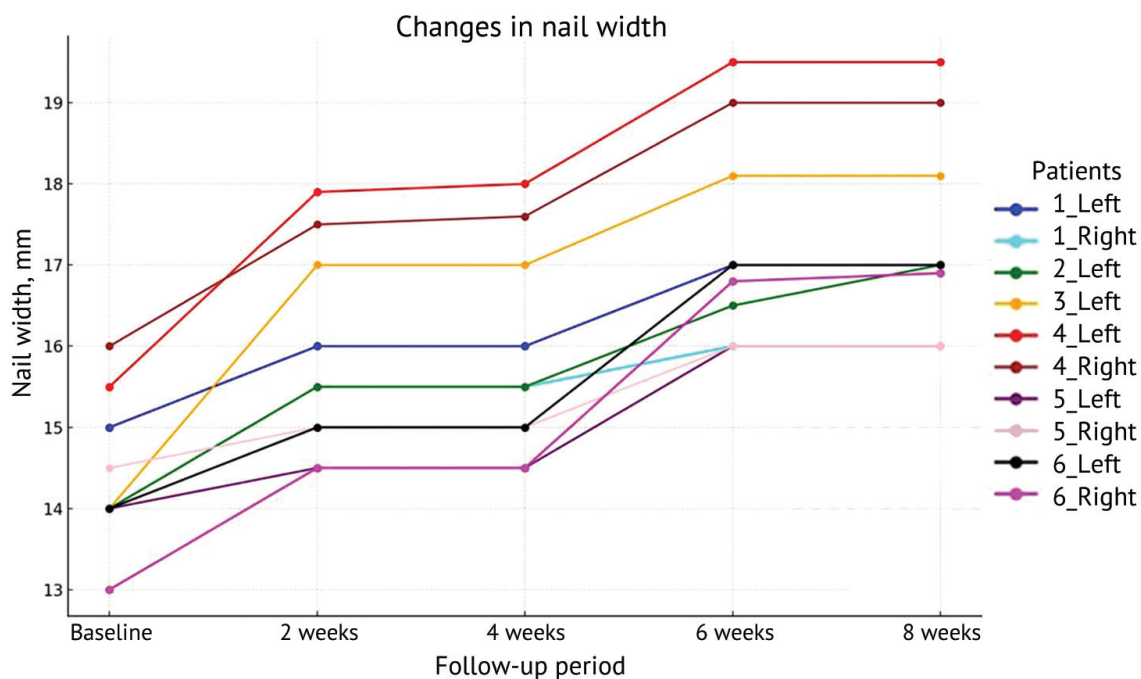


Fig. 2 Graph of nail width changes in patients

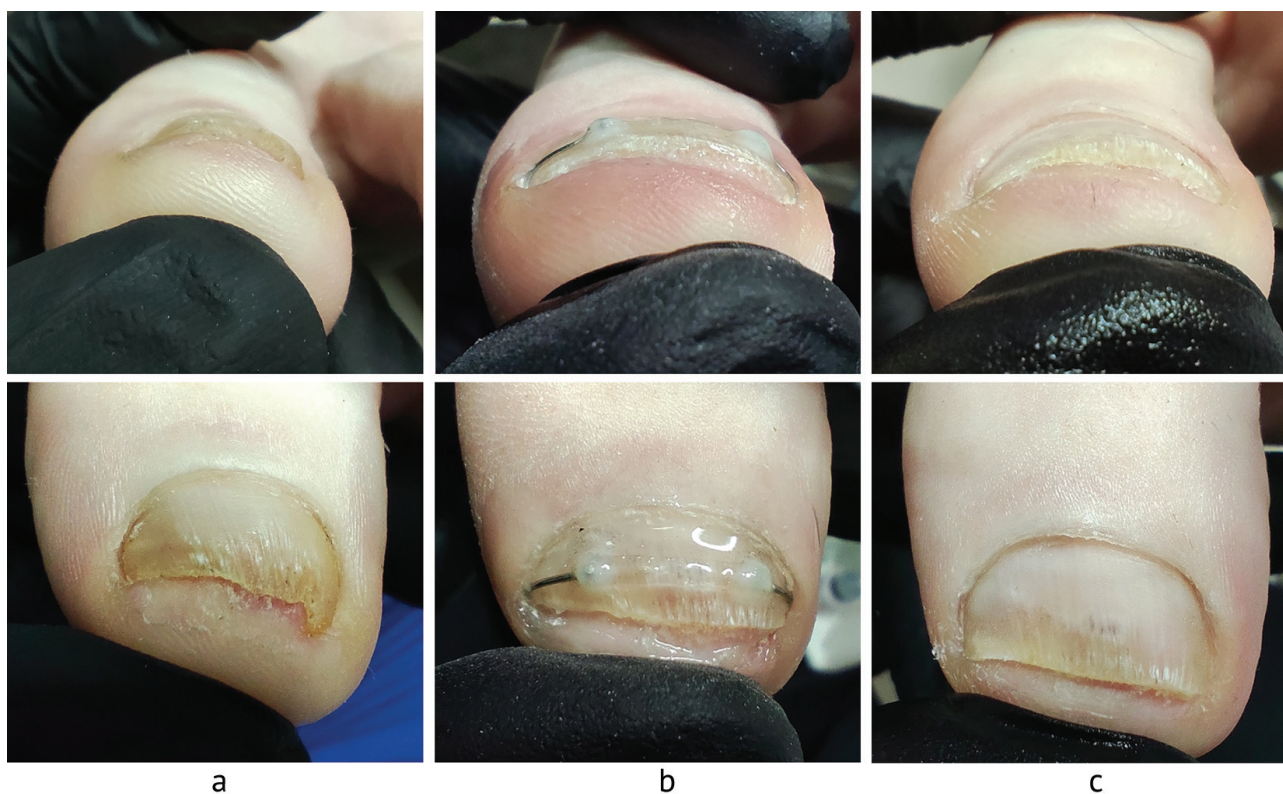


Fig. 3 Photo of the left first toe of patient No. 3, the active element "elastofors", dynamics: (a) at the baseline; (b) at four weeks; (c) at eight weeks



Fig. 4 Photo of the left first toe of patient No. 4, the active element "elastofors", dynamics: (a) at the baseline; (b) at four weeks; (c) at eight weeks

Using active elements

Elastic elements such as "elastofors" were used for thin and fragile nail plates to allow for precise adjustment of the tension force. The material was applied in two or more layers if needed, allowing for variable tension. Closed springs were used to correct more severe deformities, allowing for significant corrective force.

DISCUSSION

The findings indicated the effectiveness of the method developed for correcting nail plate deformities using elastic elements (Elastofors, Nitinol springs). The approach combined the advantages of traditional orthonyxia and innovative materials, providing a personalized effect on the nail plate. A comparative analysis of key aspects is presented below, based on current scientific research.

Advantages of the method offered:

- Highly effective for various types of deformities. The technique demonstrates a reduction in the recurrence rate, which is consistent with the results of the study by Wang and Huang [9], in which the use of nail correction staples resulted in a successful outcome in 89 % of cases. An important advantage is the adaptability of the system to the anatomy to minimize the risk of complications typical of surgical methods [3].
- Possibility of precise adjustment of tension force. The use of nitinol springs and elastofors as active elements correlates with the trend towards individualization of treatment, described in the study by Pelant et al. [10], in which the combination of materials increased the adaptability of correction. Unlike standard braces, such as Podofix, in which the tension force is fixed by the design, the proposed technique allows for adjustment of force by varying the length of the springs and elastofors layers. This is consistent with the recommendations of Dressler et al., in which

72 % of dermatologists reported the need for flexible force adjustment for complex cases [11]. Unlike rigid constructs, elastic elements can reduce the risk of overcorrection, which is critical for patients with thinning nail plates.

- The combination of two types of staples improved stable nail growth, as reported by Wang et al. [12].
- The absence of discomfort is confirmed by data on 94 % satisfaction of patients treated with non-invasive correction methods [13]. Transparent Elastophore and small size of the systems ensured aesthetics, which was critical for compliance with therapy [14].
- No need for additional instruments. The technique is accessible to all specialists familiar with most popular orthonyxia brace techniques (Fraser, ZTO, ORA) without the need to purchase specialized instrumentation. A significant advantage of the approach includes elimination of the need for expensive investments in new technical equipment, which fundamentally distinguishes it from the UniBrace system, which utilizes a unique instrumentation system [15].

Prospects for the development of the methodology

- Improved fixation. The introduction of adhesive platforms similar to those used in dermatological patches will allow for a more even distribution of pressure, reducing the risk of composite detachment [16].
- Optimization of the Elastofors immobilization technique for nail correction. The development of an alternative approach to Elastofors fixation, eliminating the use of steel wire, could form the basis for an innovative correction protocol on arbitrary areas of the nail plate. The method involves a controlled, gradual effect with the ability to precisely calibrate the gentle mechanical action on the nail tissue, which helps minimize trauma and improve the effectiveness of the therapeutic intervention.
- Use of alternative alloys in active elements:
 - titanium-molybdenum alloys — high biocompatibility and corrosion resistance [17];
 - cobalt-chromium alloys — increased strength for the correction of hypertrophic deformities [18].

CONCLUSION

The technique allows for precise adjustment of the force applied to the nail plate on each side. This is achieved by adjusting both the lever angle and the tension level of the active element in each specific correction system.

Eliminating the need for complex wire manipulation significantly reduces the time required to manufacture a custom-made correction system. The high elasticity and versatility of the active elements allow the developed systems to be used to correct various types of nail plate deformities.

Conflict of interest None of the authors has any potential conflict of interest.

Ethical approval The study was performed in accordance with ethical principles for medical research involving human subjects stated in the Declaration of Helsinki developed by the World Medical Association as revised in 2013.

Informed consent All patients were informed about the aims and methods of the study and provided written consent to participate and publish the results.

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