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Araştırma Makalesi Research Article

DESIGNED AND 3D PRINTED PLA BASED UPPER EXTREMITY FINGER ORTHOSIS

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Upper extremity,
PLA,

Abstract
The orthosis is a 3D material that supports the deformed field. These orthotic materials are used to help weak muscle function, to support muscles and joints, to correct posture, to continue to work despite unbalanced movements, and to heal fractures. Upper and lower extremity orthosis practices are available. Upper limb orthosis; shoulder, elbow, wrist, hand or fingers. Prevents or supports unwanted movements. There are various upper extremity orthoses called fingers, hand splints, hand and wrist atrophy, elbow orthosis, shoulder orthosis according to the region where they are practiced. Orthoses applied to the hand and arm are usually provided for short-term use. Nowadays, with the new generation of the industrial orthosis and 3D designs, the treatment of deformity has become possible by using simulation techniques on the biomechanical data. The purpose of this study is to discuss the advantage of the 3-dimensional PLA (Polylactic acid)-based finger-tipped orthosis on the individual's superiority against other conventional methods and designs in the treatment of upper limb finger conservative treatment.

PLA TABANLI ÜST EKSTREMITE PARMAK ORTEZI 3 BOYUTLU TASARIMI VE BASKISI

Anahtar Kelimeler
3B yazıcı,
Biyomalzemeler,
Parmak ortezi,
Üst ekstremite,
PLA,

Öz
Ortez, deformite olmuş bölgeyi destekleyen 3 boyutlu bir malzemedir. Bu ortez malzemeler, zayıf bir kas işlevine yardımcı olmak, kasları ve eklemleri desteklemek, duruşu düzeltmek, dengesiz hareketlere rağmen çalışmaya devam etmek ve kırıkları iyileştirmek için kullanılır. Üst ve alt ekstemite ortez uygulamaları mevcuttur. Üst ekstremite ortezi; omuz, dirsek, bilek, el veya parmaklar için uygulanır. İstenmeyen hareketleri önler veya destekler. Uygulandığı bölgeye göre parmak ateli, el splinti, el ve bilek atrofisi, dirsek ortezi, omuz ortezi olarak adlandırılan çeşitli üst ekstremite ortezleri vardır. Genellikle kısa süreli kullanım için el ve kola uygulanan ortezler öngörülmüştür. Günümüzde, endüstriyel yeni jenerasyon ortezi ile 3 boyutlu tasarımlarla kişiye özel biyomekanik veriler üzerinden simülasyon teknolojileri kullanılarak deformitenin tedavisi mümkün hale gelmiştir. Bu çalışmanın amacı, üst ekstremite parmak konservatif tedavisinde kişiye özel 3 boyutlu PLA (Polilaktik Asit) tabanlı parmak ateli ortezi tekniğinin diğer statik yöntem ve tasarımlara karşı avantajını tartışmaktır.

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1. Introduction

Orthoses are external devices, which are used to fix and stabilize any part of the body, to prevent or correct deformities, to protect against injuries, to maximize functions, and to reduce pain caused by deformities (Jarvik and Dalinka, 1991). The main function of the orthosis is optimization of the locomotive system with an external force, which affects joint mobility. Orthotics are important sources for; treating musculoskeletal disorders, shortening the duration of treatment, reducing tissue stress, and improving upper extremity functions (Smith and Auchincloss, 1985). The structure of the device is based on mechanical engineering principles which promote a convenient and appropriate resource that enhances comfort and efficiency. Generally, it acts as a first-class arm system with three-degree effective force and at the same time, it distributes the pressure (Sorock and Lombardi, 2002).

Orthoses are manufactured by physiotherapists, using especially low-temperature thermoplastic material. The polymer composition has different types of thermoplastic materials that can have different rubber concentrations (Jackson, 2001). These different concentrations lead to differences in stiffness, deformability, texture, protection, adhesion and finish and color factors that the therapist should consider when forming an orthotic device (Pettengill and Strein, 2002). At the present time, orthoses which are in use, have been confronted with the complaints about the design of a custom-made thermoplastic orthosis. Custom-made orthoses may cause pain in the patients and functional adverse effects, due to inappropriate mechanic properties and pressure points (Lister and Me Carthy, 1990).

The purpose of this study is to develop a functional, comfortable, innovative finger orthosis concept model which is easy to clean, install and remove; at the same time, providing the treatment of the deformity that exists.

2. Orthotics Classification & Mechanical Properties

In our clinical practice, there are many orthotic designs used to correct the biomechanics that varies according to the patient's need and therapist design preference (Wren and Yerby, 2001). For example; there are different designs, such as a ventral static orthosis, which is contemplated for daily use when a passive metacarpophalangeal extension is deficient, while at the same time correcting deformity and helping functional extension for daily use (Zhang and Chang, 2003). The best-used orthoses for the abarthrosis are the forearm, wrist and finger orthoses in the resting functional position (Bredjiklian, 2003).

Orthotics design begins with gaining data from the patient, in regard to the appropriateness of the anatomical structure of the patients and their biomechanical data. (Gerwin and Green, 1999). The main function of the orthosis is the optimization of the locomotive system. But above all, pathological necessity must be taken into consideration. Gravity force, movement and reaction forces must also be accounted for to create an orthosis (Vulpius and Strofel, 1911).
While the static device does not allow movement, the dynamic device increases patient participation more. Because it is a device that initiates or encourages movement (Baker, 1954).

Dynamic orthosis has elements that allow or facilitate movement through external force applied to prevent tissue deformation, repair or replace missing movements, and provide an autonomous power source (Bunnell, 1918). In general, mobile or kinetic orthoses are used to selectively exclude certain standard (pathological) movements and allow other movements to occur with muscle strength of the patient (Kessier, 1961).

3. Material, Method & Prototype Study

Polylactic acid (PLA+, table temperature; 60 °C, nozzles temperature; 205 °C, filament diameter; 1.75 mm ±0.05 mm, smooth, durable) material was used in the finger orthosis. PLA finger orthosis is a static system. The model that we designed, keeps the finger in a stable state from the wrist without disturbing the wrist mechanism. We used a static orthosis model to increase the fatigue resistance of the finger. Therefore, the patients will have rested their finger as if they are free from the feeling of exhaustion. Static state parameters (Figure 1) are applied with an upward F force against the gravity at the level of the wrist level with the fatigue variation (D) of the finger orthosis. The conditions affecting the fatigue variation will vary in direct proportion to the thickness of the material. Specific finger thickness, finger length (Small, Medium, Large) factors are design parameters. The technical drawings and sizes of the prototype PLA finger orthosis material have been given in Figure 2.

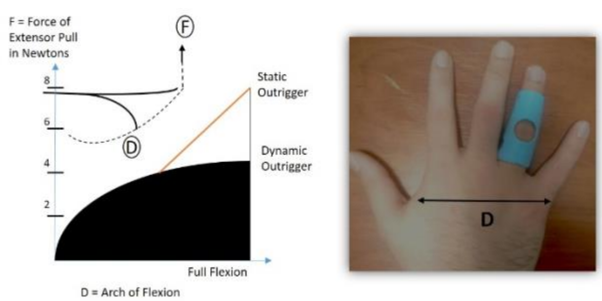
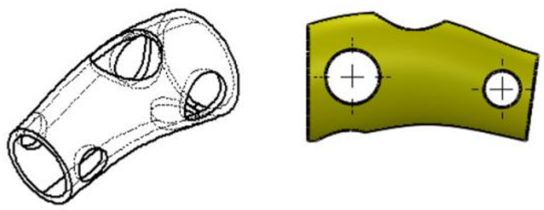


Figure 1. Static status and parametric views of the finger orthosis on the hand.



Size	cm	Inches
Small	5.0-7.0	2-1/8"-2-3/4"
Medium	7.1-8.5	2-3/4"-3-3/8"
Large	8.6-11.0	3-3/8"-4-3/8"

Figure 2. Design concept by finger biomechanical diameter (manufactured with PLA as a prototype).

4. Results & Discussion

The conceptual design is based on patients' biomechanical convenience specifically. Orthosis must be washable, ergonomic, non-allergenic and usable in every circumstance. During the designing step, these requirements tried to be fulfilled. 3D printing production method preferred for fabricating the prototype for its low cost and precision. In addition, modifying the inner surface of the orthosis can be easily obtained via 3D printing, which enables the production of the orthosis with controlled drug release, depending on the patient's situation. Prototype designed as a concept model and printed out with PLA material, based on finger alignment requirements and biomechanical data. The ultimate finger orthosis model is shown in Figure 3. The main disadvantages of finger orthoses and other orthoses are; giving off odor, triggering perspiration, itching and allergic problems due to the neoprene fabric material usage. Besides, biomechanical non-conformity causes relaxation oscillation and slippage in fabric orthoses. Using fabric orthoses, elongates production time due to the necessity of additional application tests for providing a compatible orthosis with the patient. Using a 3D printer provides manufacturing a completely unique product, which is very important for the calibration of orthoses based on the individual biomechanical variations of the patients. At the same time, the orthotic prostheses which are manufactured with a 3D printer can be mechanically immobilized with vertical load variability. It has been facilitated the ease of testing between the therapist and patients in a short period of time.

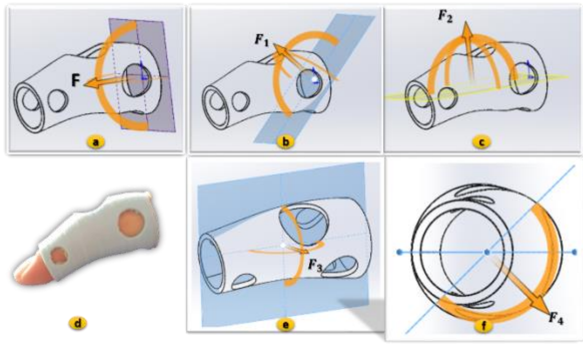


Figure 3. 3D Force modeling on finger orthoses

The purpose of this model is showing the sum of all the internal and external forces of the finger biomechanics constitute the equilibrium momentum and that the finger torque is preserved by stabilizing the variables in the hand, wrist fatigue variation strength of the orthosis internal pressure. In this way, a product that perfectly fits the design concept and needs will be introduced.

5. Conclusion

In this study, the similarities and advantages between prototype PLA finger orthotics designed for conservative treatment of upper extremity finger orthotics and other material models are discussed. The differences between the situational and dynamic orthosis should be designed and functional for the biomechanical needs of the patient. A dynamic orthosis might be more useful in some situations. Therefore; static models have more advantage than dynamic models, due to dynamic models' tendency to increase the fatigue of the injured finger.

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Conflict of Interest

No conflict of interest was declared by the authors.

References

Jarvik JG, Dalinka MK, 1991. Kneeland JB. Hand injuries in adults. Semin Roentgenol. 26, 282-299.

Smith ME, Auchincloss JM, Ali MS., 1985. Causes and consequences of hand injury, J Hand Surg, 10, 288-292.

Sorock GS, Lombardi DA, Hauser RB, Eisen EA., 2002. Acute traumatic occupational hand injuries: Type, location, and, severity. J Occup Environ Med. 44, 345-351.

Jackson LL., 2001. Non-fatal occupational injuries and illnesses treated in hospital emergency department in the United States. Inj Prev. 7, 121-126.

Pettengill K M, van Strein G., 2002. Postoperative management of flexor tendon injuries. In: Hunter M, Rehabilitation of the hand and upper extremity 5th ed St Louis, Missouri, Mosby. 431-456.

Lister G.D. Flexor tendon. In JG. Me Carthy ed., 1990. Plastic Surgery. Vol: 7, pp:. Philadelphia, W.B. Saunders. 7, 4516-4564.

Wren T.A.L, Yerby .S.A, Beaupre G.S, Carter D.R., 2001. Mechanical properties of human Achilles tendon. Clin. Biomech. 16, 245-251.

Zhang A.Y, Chang J., 2003. Tissue engineering of flexor tendons. Clin. Plastic. Surg. 30, 565-572.

Bredjiklian P.K., 2003. Biologic aspects of flexor tendon laceration and repair. J. Bone Joint Surg. 85A, 539 549.

Gerwin M. Cerabral palsy. In D.P. Green, R.N. Hotchkiss, W.C. Pederson (eds), 1999. third ed. Green's Operative Hand Surgery. New York, Churchill Livingsteone. 1, 259-286.

Vulpius O., Strofel A., 1911. In Enke Ferdinand ed. Orthopadische Operatlonslehre, Stuttgart. 29-30.

Baker L.D., 1954. Triceps surae syndrome in cerebral palsy: an operation to aid its lelief. Arch Surg. 68: 216-221.

Bunnell. S., 1918. Repair of tendons in the fingers and two new instruments. Surg. Gynocol. Obstet. 10, 103-110.

Kessler, I., 1961. Primary repair without immobilization of flexor tendon division within the digital sheet. Acta, Orth. Scan. 40, 587-601.