Smart splint for diagnosis during initial stage of treatment

Conference Paper · October 2020

DOI: 10.1145/3434780.3436610

4 authors:

José María de Agustín Del Burgo
Universidad Politécnica de Madrid

Fernando Blaya
Universidad Politécnica de Madrid

Roberto D'Amato
Universidad Politécnica de Madrid

Juan A Juanes
Universidad de Salamanca

Smart splint for diagnosis during initial stage of treatment

José M. de Agustín del Burgo
Universidad de Salamanca, Salamanca, Spain
id00792219@usal.es

Fernando Blaya Haro
Universidad Politécnica de Madrid, 28012 Madrid, Spain
Fernando.blaya@upm.es

Roberto D'Amato[†]
Universidad Politécnica de Madrid, 28012 Madrid, Spain
r.damato@upm.es

Juan Antonio Juanes Méndez
VisualMed Systems Group, Universidad de Salamanca, Salamanca, Spain
jajm@usal.es

ABSTRACT

Nowadays, after suffering certain musculoskeletal rupture injuries, the only treatment available is the use of plaster cast. However, this type of treatment, that is similar to the used originally by the Persians in the 10th century, has some disadvantages, that are still present nowadays. It usually causes discomfort due to the weight (around 1,5kg) and the restrictions to refresh the skin. Moreover, it is not submersible and it is not possible to apply certain kind of treatments, like ultrasounds or infrared. It also may appear complications at the vascular, muscular or even articular level due to these problems.This project aims to show there is a really possible option that would solve these inconvenient. Moreover, it would allow a faster and better recovery, combining 3D prototyping, 3D scanning, medicine, engineering and materials evolution. This study proposes the use of sensor integration inside the splints to detect any kind of problem during the treatment process. These sensors get different data like pressure, color, humidity and temperature from the splint. After that, these parameters are analyzed to determine any unexpected evolution and sent by telematic channels to be consulted remotely by a specialist.

CCS CONCEPTS

• **Applied computing** → Life and medical sciences; Health informatics.

KEYWORDS

Smart Splint, 3D printing, Sensors, Treatment evolution

ACM Reference Format:
José M. de Agustín del Burgo, Fernando Blaya Haro, Roberto D'Amato[†], and Juan Antonio Juanes Méndez. 2020. Smart splint for diagnosis during initial stage of treatment. In *Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'20), October 21–23, 2020, Salamanca, Spain.* ACM, New York, NY, USA, 9 pages. https://doi.org/10.1145/3434780.3436610

TEEM'20, October 21–23, 2020, Salamanca, Spain

ACM ISBN 978-1-4503-8850-4/20/10…$15.00
https://doi.org/10.1145/3434780.3436610

1 INTRODUCTION

Industrial Design and Advanced Manufacturing has made it possible an enormous growing of New Industry. Moreover, the optimization of the process [1], [2], the new concept of materials [3] and the decrease of costs [4] are some achievements that has produced an expansion of these technics further than the industrial area to applications known as Bioengineering [5].

The implementation of fused deposition modelling (FDM) or selective laser fusion (SLM) in the healthcare industry, allows benefits in terms of design and customization of medical devices and implants. Clear examples of these advances are craniomaxillofacial surgery prothesis [6], different therapies for obstructive sleep apnea (OSA) [7], [8], orthopedics surgery [9] or rehabilitation [10], Moreover, it simultaneously improves wearing comfort and hygiene. Many developments have been carried out, like exoskeletons [11], assistive devices or prosthesis. Although these specialties are very demanded [12] specially in developed countries, it is necessary a level of maturity and development technologically speaking, to get a real change in the actual model.

Also, the incursion of this new 3D techniques in medical processes, makes it possible to include smart systems that will allow to analyze different medical states of the evolution process. These kinds of systems that includes small electronic devices, microprocessors, programming systems and data communication, are responsible of monitoring and treatment of different data, that could also be sent to an application or a mobile device [13]. Moreover, these data can be compared and treated using Artificial Intelligence in medicine [14] to detect any kind of problems, so it opens a big new world of treatment and diagnostic possibilities.

This study focuses on the implementation of all of these concepts. It will be showed the development and prototyping of a smart immobilization splint using a 3D scanner using biocompatible material. This splint will incorporate different windows for possible treatments like lymph drainage, iontophoresis, ultrasound, laser or electrostimulation. It will also include sensors that will be placed to get pressure, temperature, color skin and humidity of the immobilized area.

2 MATERIALS AND METHODS

In this section it is explained and presented the different steps that are followed to design a 3D virtual model of the splint that will be produced later. In this case, it was used as model the right leg of a 29 years old volunteer, that will be the basis to create digitally the splint where the tests will be carried out. In this case, there was

4 DISCUSSIONS

It is possible to find a relation between temperature patterns and medical conditions [27-29]. This is due to metabolism and local blood flow, that generates located temperature variations. Also, bone formation other disease processes are also be responsible of a reduction in blood flow. This fact, will produce alterations in surface temperature [30]. It is possible to see in the different charts, that the temperature, pressure and humidity variations, are perfectly detected by the sensors mounted on the splint.

It would also be possible to create a digital mapping of the temperatures under the splint by adding more sensors. All these collected data quantify temperature changes in skin surface that may be both cold and hot responses, which may co-exist with pain during inflammatory processes [15]. The possibility of getting a continuous monitoring of these parameters, allows to know the progression at any time of the treatment. This makes it possible an early detection of joint, vascular or muscular complications that are difficult to observe if the immobilization splint is not removed previously.

It is possible to see that the sensor in contact with the skin detects a temperature slightly lower than the normal body temperature. This fact is due to the gradient of temperature that occurs on the metallic sensor surface. The sensor has about a 40% of the surface in contact with the skin. The 60% of the surface is not in contact by the skin due to its cylindrical form. Due to this, it comes up a difference of temperature on the sensor surface, between different areas. Due to the thermal conductivity, the metallic surface tends to get an equilibrium between the different areas [30]. Finally, the sensor gets a temperature that is not the real skin temperature whereas it is the mean temperature obtained from the whole surface. However, this is not a problem, as it is enough information to detect both decremental and incremental temperature changes.

The humidity and pressure values are also correctly acquired. As with the temperature, it is possible to detect variations due to internal sweating, and pressure produced by an inflammatory process.

Finally, by using the RGB sensor, it is possible to detect variations in the three components of the light (red, green and blue). When a hematoma shows up, the concentration of blood on a determinate area, produces a change on the color of the skin. The sensor is able to detect a variation of the three studied components of the light, so it avoids the necessity of removing the splint to detect the creation of a hematoma.

5 CONCLUSIONS

With this innovative project, it is intended to provide an evolution for the traditional splints, that have remained practically intact since their invention in the tenth century.

The 3D FDM splint fabrication makes it possible to create different housings for the implementation of different sensors on the splints. These sensors may be used to get different information during the treatment process, to be monitored by a specialist remotely. Moreover, the use of 3D printing allows to create different holes to apply different treatments that might make it shorter de length of the treatment.

As it is showed in this study, this autonomous system, powered by a battery, is able to get the information from the sensors. This information and different parameters considered at the beginning of this study, may be consulted remotely.

It is proposed as an evolution of this study, the incorporation of an algorithm that may notify of an unexpected evolution by using the different collected data.

REFERENCES

[1] U. Jammalamadaka and K. Tappa, "Recent advances in biomaterials for 3D printing and tissue engineering," Journal of Functional Biomaterials. 2018.
[2] A. Bandyopadhyay, S. Bose, and S. Das, "3D printing of biomaterials," MRS Bull., 2015.
[3] H. N. Chia and B. M. Wu, "Recent advances in 3D printing of biomaterials," J. Biol. Eng., 2015.
[4] F. Blaya, P. S. Pedro, J. L. Silva, R. D'Amato, E. S. Heras, and J. A. Juanes, "Design of an Orthopedic Product by Using Additive Manufacturing Technology: The Arm Splint," J. Med. Syst., vol. 42, no. 3, 2018.
[5] S. Affatato, A. Ruggiero, J. S. De Mattia, and P. Taddei, "Does metal transfer affect the tribological behaviour of femoral heads? Roughness and phase transformation analyses on retrieved zirconia and Biolox®Delta composites," Compos. Part B Eng., vol. 92, pp. 290–298, May 2016.
[6] S. Ghai, Y. Sharma, N. Jain, M. Satpathy, and A. K. Pillai, "Use of 3-D printing technologies in craniomaxillofacial surgery: a review," Oral and Maxillofacial Surgery, vol. 22, no. 3. Springer Verlag, pp. 249–259, Sep-2018.
[7] N. M. García, F. Blaya, E. L. Urquijo, E. S. Heras, and R. D'Amato, "Oral appliance for Obstructive Sleep Apnea: Prototyping and Optimization of the Mandibular Protrusion Device," J. Med. Syst., vol. 43, no. 5, p. 107, May 2019.
[8] N. Montesdeoca, E. Lechosa, F. B. Haro, R. D'Amato, and J. A. Juanes, "Design of thermoplastic oral appliance with mouth opening control to treat obstructive sleep apnea," in ACM International Conference Proceeding Series, 2019, pp. 404–410.
[9] J. S. Mulford, S. Babazadeh, and N. Mackay, "Three-dimensional printing in orthopaedic surgery: review of current and future applications," ANZ journal of surgery, vol. 86, no. 9. Blackwell Publishing, pp. 648–653, Sep-2016.
[10] C. Lunsford, G. Grindle, B. Salatin, and B. E. Dicianno, "Innovations With 3-Dimensional Printing in Physical Medicine and Rehabilitation: A Review of the Literature," PM and R, vol. 8, no. 12. Elsevier Inc., pp. 1201–1212, Dec-2016.
[11] J. Cernohorsky and M. Cadek, "Smart rehabilitation splint," in Mechanisms and Machine Science, 2017.
[12] J. Evill and O. Evill, "Cortex Evill," 2013. .
[13] J. M. De Agustín Del Burgo, F. Blaya Haro, R. D'Amato, and J. A. Juanes Méndez, "Development of a Smart Splint to Monitor Different Parameters during the Treatment Process," Sensors, vol. 20, no. 15, p. 4207, Jul. 2020.
[14] P. Hamet and J. Tremblay, "Artificial intelligence in medicine," Metabolism., 2017.
[15] F. Blaya, P. S. Pedro, A. B. S. Pedro, J. Lopez-Silva, J. A. Juanes, and R. D'Amato, "Design of a Functional Splint for Rehabilitation of Achilles Tendon Injury Using Advanced Manufacturing (AM) Techniques. Implementation Study," J. Med. Syst., vol. 43, no. 5, 2019.
[16] X. Ju, J.-C. Nebel, and J. P. Siebert, "3D thermography imaging standardization technique for inflammation diagnosis," in Infrared Components and Their Applications, 2005, vol. 5640, p. 266.
[17] T. Schlereth, P. D. Drummond, and F. Birklein, "Inflammation in CRPS: Role of the sympathetic supply," Auton. Neurosci. Basic Clin., vol. 182, pp. 102–107, May 2014.
[18] Dallas Semiconductor, "Programmable Resolution 1-Wire®Digital Thermometer," 2002.
[19] L. Aosong Electronics Co., "Digital-output relative humidity & temperature sensor/module DHT22 (DHT22 also named as AM2302)," 2015.
[20] "Film Pressure Sensor DF9-40@10kg V2.0."
[21] "TCS3472 COLOR LIGHT-TO-DIGITAL CONVERTER with IR FILTER." [Online]. Available: https://cdn-shop.adafruit.com/datasheets/TCS34725.pdf. [Accessed: 30-Apr-2020].
[22] "ESP32 Series Datasheet Including," 2020.
[23] F. B. Haro, J. Lopez-Silva, P. S. Pedro, J. A. Juanes, A. B. S. Pedro, and R. D'Amato, "Design and prototyping by additive manufacturing of a functional splint for rehabilitation of Achilles tendon intrasubstance rupture," in ACM International Conference Proceeding Series, 2018.
[24] F. B. Haro *et al.*, "Monitoring an Analysis of Perturbations in Fusion Deposition Modelling (FDM) Processes for the Use of Biomaterials," J. Med. Syst., vol. 43, no. 5, p. 109, May 2019.
[25] F. B. Haro, J. M. de Agustín del Burgo, R. D'Amato, M. I. Marcos, E. S. Heras, and J. M. G. Alonso, "Monitoring of the additive manufacturing process for the use of biomaterials in medical field," in Proceedings of the Sixth International Conference on Technological Ecosystems for Enhancing Multiculturality - TEEM'18, 2018, pp. 428–432.

[26] J. M. D. A. Del Burgo, R. D'Amato, J. A. J. Méndez, A. S. Ramírez, F. B. Haro, and E. S. Heras, "Real time analysis of the filament for FDM 3D printers," in ACM International Conference Proceeding Series, 2019.
[27] R. LAWSON, "Implications of surface temperatures in the diagnosis of breast cancer.," Can. Med. Assoc. J., vol. 75, no. 4, pp. 309–311, 1956.
[28] B. Ströberg, "The Use of Thermography in Equine Orthopedics," Vet. Radiol., vol. 15, no. 1, pp. 94–97, Jan. 1974.
[29] L. Wang *et al.*, "Bisphosphonates Inhibit Pain, Bone Loss, and Inflammation in a Rat Tibia Fracture Model of Complex Regional Pain Syndrome," Anesth. Analg., vol. 123, no. 4, pp. 1033–1045, Oct. 2016.
[30] C. H. Rundle *et al.*, "Microarray analysis of gene expression during the inflammation and endochondral bone formation stages of rat femur fracture repair," Bone, vol. 38, no. 4, pp. 521–529, Apr. 2006.