

Article

Using Photogrammetry to Obtain 3D-Printed Positive Foot Casts Suitable for Fitting Thermoconformed Plantar Orthoses

Ana María Pérez Pico ¹, Félix Marcos Tejedor ², Luis Carlos de Cáceres Orellana ^{3,4},
Pablo de Cáceres Orellana ^{3,4} and Raquel Mayordomo ^{4,*}

¹ Department of Nursing, Centro Universitario de Plasencia, Universidad de Extremadura, 10600 Plasencia, Spain

² Department of Medical Sciences, Faculty of Health Sciences, Universidad de Castilla-La Mancha, 45600 Talavera de la Reina, Spain

³ Davonde 3D, 06140 Badajoz, Spain

⁴ Department of Anatomy, Centro Universitario de Plasencia, Universidad de Extremadura, 10600 Plasencia, Spain

* Correspondence: rmayordo@unex.es; Tel.: +34-636526498

Abstract: The use of photogrammetry provides an inexpensive, alternative method that can simplify the processes traditionally carried out in the orthotics workshop. The objectives of this study are to develop a method based on photogrammetry to obtain 3D-printed positive foot casts for fabricating thermoconformed orthoses from a negative cast in phenolic foam. Using a basic Smartphone, a photo capture protocol for feet, free software and a 3D printer, we tested the suitability of the positive cast obtained to fabricate custom foot orthoses using thermoconformed 3 mm polypropylene in the orthotics laboratory. The results show that digitally fabricated casts provide a very close replicate of the positive casts obtained traditionally through plaster casting (maximum dimension discrepancy between casts of 2 mm in length and 0.4 mm in forefoot, midfoot and rearfoot measurements). They are also suitable for the process of fabricating 2- and 3-mm polypropylene thermoconformed plantar orthoses. Photogrammetry can be used as a new method to obtain a positive 3D foot cast suitable for fabricating custom orthoses, in a valid, safe, cleaner and more lasting procedure that removes the process of plaster casting.



Citation: Pérez Pico, A.M.; Marcos Tejedor, F.; de Cáceres Orellana, L.C.; de Cáceres Orellana, P.; Mayordomo, R. Using Photogrammetry to Obtain 3D-Printed Positive Foot Casts Suitable for Fitting Thermoconformed Plantar Orthoses. *Processes* **2023**, *11*, 24. <https://doi.org/10.3390/pr11010024>

Received: 21 November 2022

Revised: 7 December 2022

Accepted: 20 December 2022

Published: 23 December 2022



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Keywords: photogrammetry; foot orthoses; additive manufacture; 3D photography; positive cast; 3D printed

1. Introduction

Therapy using foot orthoses (FO) to balance the musculoskeletal system in static and dynamic balance is considered a front-line treatment. By redistributing plantar pressures, these treatments aim to prevent, alleviate or treat the pathological process whose etiology is the cause of a functional musculoskeletal imbalance [1]. A wide range of FO are available, and various techniques are used to fabricate them. However, it has been demonstrated that custom FO are the gold standard for improving foot conditions, as they fit better and outperform non-custom or off the shelf orthoses [2,3], primarily because the manufacturing process involves fitting techniques, either directly onto the foot or a cast of the foot.

The most frequent method of fabricating thermoconformed, custom FO fitted to the user is based on obtaining a negative cast of the foot. This initial process is essential for customizing orthopedic treatments and ensuring satisfactory treatment. Several studies have assessed the process for obtaining casts and modifying them and compared the various methods used. The most habitual method is probably by obtaining a negative cast, using either plaster strips or phenolic foam (foam box casting), although FO are also made using alginates, vacuum forming and 3D scanning [4,5]. The positive cast is obtained by filling the negative cast with plaster that can be modified by the clinician after

hardening if necessary. Once the replicate of the foot has been obtained, the pattern of the FO thermoconformed material is fitted onto the positive cast then sanded and polished before the other elements chosen for the final product are added [3,5,6].

However, technological advances have permitted the use of various techniques for collecting anatomy data in 3D (3D Anatomical Data Acquisition Technologies). These technologies allow us to directly obtain positive casts of the foot for subsequent computer-aided design (CAD) and fabrication of orthoses using computer aided manufacture (CAM). They include 3D scanning of non-weight-bearing feet, Computed Tomography, and Optical Motion Capture System [7,8]. The FO is then fabricated using additive manufacturing or 3D printing, a technique widely used in healthcare and medicine with an extensive range of applications in odontology, tissue engineering and regenerative medicine, custom tissue models, medical devices, anatomical models, and the manufacture of custom FO [8–11]. Fabricating FO by 3D printing achieves results more quickly and cleanly and allows a wider range of modifications that can be made more easily. However, FO fabrication with 3D methods requires a substantial initial investment and the financial return is very long term [8]. One way of minimizing this major disadvantage is through photogrammetry, which uses 2D photos to create 3D images and, through a digitalization process, obtains the anatomical model [12–15]. Although many studies have examined this technique, mainly for the manufacture of facial models, we have found no works in the field of podiatry about their use in FO fabrication. The novelty in this study is the use of photogrammetry. The main objective of this study is to develop a method to produce 3D-printed positive casts of the foot based on photogrammetry for the fabrication of thermoconformed plantar orthoses with a safer, cleaner and adequate time management.

2. Materials and Methods

2.1. Participant Selection

Three members of the university community were invited to take part. After the purpose of the study and the ethical aspects of the research had been explained to them, they agreed to take part voluntarily and signed an informed consent form.

2.2. Fabricating Casts Using the Traditional and the Digital Method

2.2.1. Obtaining the Negative Cast of the Foot in Phenolic Foam

A podiatrist performed the foam box casting (Fastprint®, Herbitas, Valencia, Spain) in partial weight-bearing, following the protocol described by Benhamú (2004) [16] (Figure 1A), ensuring that the foot had been completely inserted, the forefoot and rearfoot were maintained on the same plane of depth and the morphology of the cast correlated to the foot. Eight reference anatomical landmarks were marked on the phenolic foam (Figure 1B) to measure the length and width of the cast: midpoint of longest toe, midpoint of the rear of the heel, and the points of maximum width, both internal and external, of the forefoot (first and fifth metatarsal head), midfoot (styloid apophysis and first cuneiform) and rearfoot (internal and external malleolus).

2.2.2. Obtaining the Positive Foot Cast in Plaster

The phenolic foam cast was filled with plaster and left to dry, before removing the phenolic foam and cleaning the cast. The process is shown in Figure 1C–E.

The traditional method for the creation of plantar orthoses requires having at least one full working day to make them. The first step is taking the cast using phenolic foam (validated method for obtaining the negative of the foot). Once we have the negative cast, we must turn it into a positive cast by filling the phenolic foam with plaster (Figure 1C). This process requires at least 8–12 hours of drying for subsequent handling. If the positive plaster cast is not dry enough it can break during the fitting process of the orthosis, which is why most professionals spend a full day just in this drying process. If the positive breaks, it is impossible to recover the negative cast and therefore the whole process must be carried out again, that is, call the patient to come back for consultation, take another negative cast

with phenolic foam and start the filling process. Once we have the positive cast, the rest of the process is the same as for the digital process. This process requires at least 1 or 2 more hours.



Figure 1. Procedure from taking the negative cast to creating the positive casts with both techniques. (A): Obtaining cast in phenolic foam (negative cast of the foot). (B): References on negative cast. (C): Plaster casting. (D): Cleaning the plaster cast. (E): Positive plaster cast obtained by traditional method. (F) and (G): Photogrammetry and overlapping photo method on the negative cast of the foot using a smartphone. (H): 3D modeling on a PC. (I): 3D printing of positive cast. (J): Positive cast obtained by digital manufacture.

2.2.3. Obtaining the 3D Printed Positive Cast Using Photogrammetry

The digital process can simplify the process, avoiding the risk of the positive mold being broken. In addition, the process of digitizing the negative cast and preparing the impression process for the creation of the positive cast can be done in 30 minutes (to prepare the images to send to the printer and 9.57 h for the impression of the positive casts of the foot in 3D) which is relatively easy for the professional to manage effectively. In addition, the printing process does not require the professional to be present, which is also an advantage. Furthermore, de plastic material is even cheaper than plaster. Once we have the digital positive mold, we have to make the orthosis pattern in the same way as in the traditional process.

A photo target was placed on the phenolic foam. At least 14 photos in jpg format were taken with photo overlapping of the negative cast of the foot using a smartphone (Mi A1) manufactured by Xiaomi (Xiaomi Headquarters Haidian, Beijing, China) (Figure 1F), maintaining the cast in the same position and the same camera settings and angle for the photos. The smartphone was moved between photos and each photo overlapped the previous one by at least 60%. Photos with projected shadow, shine or reflections were discarded. White light was used, avoiding sunlight. The images were sent to the image processor in Agisoft Metashape Professional (Version 1.6.2 build 10247 (64 bit), Agisoft LLC/Saint Petersburg/Russia, 2020), avoiding alteration of the images using flash memory or through Google drive. The images were processed until a 3D model of the negative

cast of the foot was obtained in OBJ format and imported to the modeling program 3D Meshmixer 3.5 (Version 3.5.474 Autodesk Research/California/USA, 2018) to obtain the positive model scaled to the reference target, then exported to the 3D model in STL. The 3D model in STL was imported into Z-SUIT (Version 2.12.2.0 Zortrax/Olsztyn/Poland, 2017) (Figure 1G). The geometry of the 3D model and the settings of the parameters of the material (Z-PCABS) were assessed and the additional manufacturing material was configured after assessing the manufacturing stages and creation of the 3D model (Figure 1H), by additive manufacturing with the Zortrax M200 printer (Figure 1I). The printer has a dimensional accuracy of $\pm 0.2\%$ volume deviation and allows a positive cast to be obtained in 3D using digital methodology (Figure 1J). The parameters of the additive manufacturing process were the following:

- Printer: m200;
- Support type: Automatic;
- Support: 20° ;
- Material: Z-PCABS;
- Nozzler diameter: 0.4 mm;
- Layer: 0.19 mm;
- Quality: normal;
- Infill: 60%;
- Printed time: 9 h 57 m;
- Material needed: 236 g.

2.3. Verifying the Similarity of Positive Casts

Once the two casts had been obtained, measurements were taken for comparison with Powerfix® calliper (accuracy 0–100 mm ± 0.02 mm and 100–150 mm ± 0.03 mm). A Cescorf® anthropometric tape measure with 1 mm accuracy was used to measure the length of the casts. The following parameters were measured (Figure 2):

- Cast length, taking as a reference the most distal point of the longest toe and the rear of the heel (Figure 2A,B).
- Foot width, measuring the distances between the reference anatomical landmarks made on the cast: forefoot, midfoot and rearfoot (Figure 2C–H).

2.4. Creating the Thermoconformed Orthoses

The relief of the reference points of both casts was removed. The orthoses were made following the method of Doxey [17] and Levi [18]. The orthosis pattern was made according to the morphological features of the cast, cut out on 3 mm polypropylene and placed in an oven (Comelec, model n°: HO451 ICR) at 180° , following the manufacturer's instructions. The pattern was fitted onto the positive cast using a PODIATECH® vacuum. The shell was finished by polishing in the PODOMAC® polisher (Figure 3).

2.5. Fitting the FO on the Participant's Foot

The podiatrists then verified the fit of the orthosis on the positive cast and finally on the participant's foot. The orthosis was considered to fit well when the complete outline fitted to the participant's foot without being tight (Figure 4). Participants were asked about their perception of the fit of both treatments and whether they considered the two orthoses fitted equally, similarly or differently.

2.6. Statistical Tests

Data were processed using IBM SPSS Statistics for Windows, version 22.0 (IBM, Armonk, NY, USA, 2020). To study the normality of the data, the Shapiro–Wilk and Graphics Q-Q tests were performed, with normality tests and the homoscedasticity test (Levene test). For the study of contrasting measurements, the Student's *t* test for independent samples was used. A significance level of 5% was established, thus rejecting the hypothesis of equality with *p*-values less than 0.05.

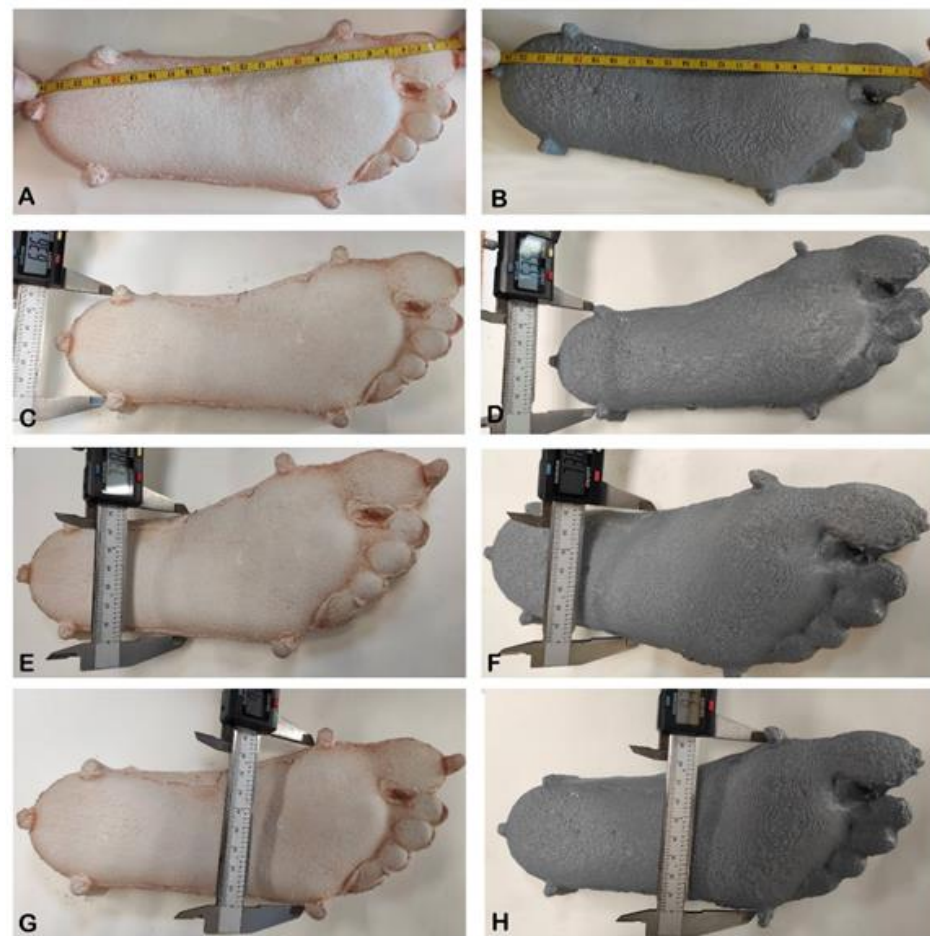


Figure 2. Method for verifying dimensions of the positive casts with a tape measure and Powerfix caliper. Measurement of length (A and B), rearfoot (C and D), midfoot (E and F) and forefoot (G and H) of the positive casts made of plaster and plastic, respectively.

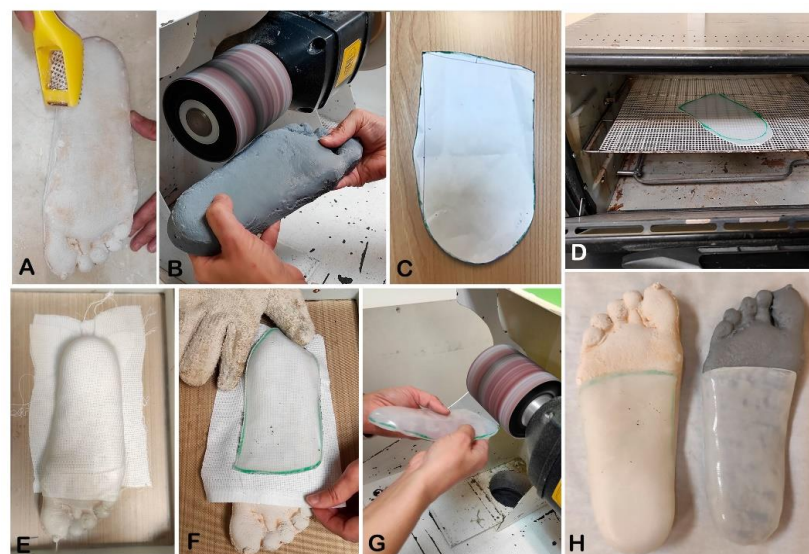


Figure 3. Method for making orthoses in both positive casts following the protocol of Doxey (Doxey 1985) and Levi (Levi Bensaully 2003). A and B: removing the reference points from the positive casts. C: Pattern for cutting out the orthosis materials. D: Polypropylene in the oven. E and F: Fitting the orthoses. G: Polishing the orthoses. H: Orthoses fitted on the positive casts.



Figure 4. Fitting the orthoses obtained using the traditional and digital method. **A** and **B**: Rear view of the orthoses obtained through the traditional and digital method, respectively. **C** and **D**: Lateral view of the orthoses obtained through the traditional and digital method, respectively. **E** and **F**: Medial view of the orthoses obtained through the traditional and digital method, respectively. **G**: Rear view of participant on tiptoe to show the retrocapital fit of the orthosis.

3. Results

3.1. Preliminary Tests and Validations: Comparison of Positive Casts Obtained by the Two Methods

The 12 positive casts obtained (six by the traditional method and six by reverse engineering) were measured with a caliper. The dimensional accuracy of the different positive casts from the same participant was determined using a Powerfix caliper. The dimensional discrepancies between each area chosen for measuring were compared: length, forefoot width, midfoot width and rearfoot width. The maximum discrepancy in length observed when measuring the plaster casts and the 3D casts of the same foot and participant was 2 mm. The maximum discrepancies in width measurements were 0.3 mm in the forefoot, 0.4 mm in the midfoot and 0.34 mm in the rearfoot (see Table 1).

Table 1. The detail of dimension measurements of the cast obtained through traditional and digital fabrication described.

Participant and Foot Measured	Method for Obtaining Casts	Length Measurement	Width Measurement		
			Forefoot	Midfoot	Rearfoot
Participant 1 RF	Traditional	242 mm	95.62 mm	75.35 mm	63.57 mm
		240 mm	95.32 mm	75.35 mm	63.23 mm
Participant 1 LF	Traditional	244 mm	93.70 mm	73.82 mm	63.67 mm
		243 mm	93.47 mm	73.60 mm	63.52 mm
Participant 2 RF	Traditional	247 mm	89.79 mm	68.55 mm	59.12 mm
		246 mm	89.69 mm	68.36 mm	59.03 mm
Participant 2 LF	Traditional	251 mm	90.54 mm	71.48 mm	55.44 mm
		250 mm	90.26 mm	71.40 mm	55.25 mm
Participant 3 RF	Traditional	236 mm	89.70 mm	71.76 mm	59.70 mm
		235 mm	89.43 mm	71.37 mm	59.42 mm
Participant 3 LF	Traditional	236 mm	93.84 mm	70.69 mm	60.13 mm
		236 mm	93.79 mm	70.40 mm	59.91 mm

RF = right foot, 3D = Three dimensions, mm = Millimeters.

Statistical analysis of the differences of means of the length and width measurements of the forefoot, midfoot and rearfoot between the methods studied showed no significant difference in any of the measurements taken (p -values > 0.05) (see Table 2).

Table 2. Contrast of means of the measurements taken on the cast by fabrication method.

Cast Measurement	Method Used to Obtain Casts	Mean (mm)	Std. Deviation	p -Value Student t
Length	Traditional	242.66	± 5.98	0.775
		241.66	± 5.81	
Forefoot width	Traditional	92.20	± 2.51	0.888
		91.99	± 2.50	
Midfoot width	Traditional	71.60	± 1.90	0.915
		71.74	± 2.44	
Rearfoot width	Traditional	60.27	± 3.08	0.907
		60.06	± 3.05	

mm = Millimeters, D = Deviation, 3D = Three dimensions.

3.2. Results of the Feasibility Analysis of the Cast for Thermoconforming Orthoses

After measuring the dimensions on both casts, the feasibility of the 3D cast obtained through reverse engineering for thermoconforming 2- and 3-mm polypropylene orthoses was assessed.

The podiatrist made the orthosis pattern, heated the polypropylene to 110 °C in an oven (Comelec, model n°: HO451 ICR) and fitted it in the vacuum (−0.50 pressure bar) onto the 3D cast, ensuring that it did not deform and kept the same initial measurements. The plantar orthoses obtained fitted perfectly to the cast and to the participant's foot (Figure 4). When participants were asked about their perceptions, they said the two orthoses fitted equally, thus demonstrating the feasibility of the 3D printed cast for the purpose studied. The results presented here shows that it is possible to get a digital positive cast and improve the process not only in an economic way (in the medium/long term). There is an improvement of the process in the preparation of the positive cast with digital processes compared to the traditional method. Plaster is very cheap, but it has other drawbacks, such as a long adequate drying time (more than 24 hours), its handling requiring a specific space for its processing, and being very dirty and potentially clogging up the clinic's pipes; thus, it needs a decanter, which represents an extra investment in the drainage system of the pipes.

4. Discussion

Custom orthoses are the gold standard for improving musculoskeletal balance, mainly of the lower limbs and specifically of the foot, by redistributing plantar pressures [1,2,19]. A key element of fabricating a good custom orthosis is obtaining an adequate positive cast of the foot [5,20]. Several authors have examined the importance of the cast in fabricating orthoses and prostheses, and even shoes [21,22]. Obtaining the positive cast traditionally starts with making an impression of the foot (through a negative cast). The authors have compared the different methods of obtaining the cast and analyzed the efficiency of each method. However, the final decision on the choice of cast will depend on the health professional and the condition requiring treatment [5,20]. After recent advances, computer-aided design and manufacture technology (CAD/CAM) has been developed across the health field [7,23–25], including 3D printing to obtain positive casts. The major disadvantage is the need for an initial investment in scanning technologies that generate a return in the long term. Moreover, according to Barrios-Muriel et al (2020), there is no standard procedure for acquiring body morphology, despite the many procedures described [23]. However, this does not occur with photogrammetry. We provide a method for obtaining impressions of 3D-printed positive casts of the foot using photogrammetry, enabling fabrication of a 3D cast without the high costs associated with digital technologies [8,26,27]. Moreover, our method does not support the results of authors who reported large differences between

the real measurements and the 3D model obtained using their methods [26], which is a considerable disadvantage when providing this type of custom treatment. At this level, the differences we found by fabricating the 3D cast using photogrammetry and comparing it with a cast obtained by the traditional method using phenolic foam are minimal and are slightly lower in most measurements taken on the 3D cast, but with no statistically significant differences. This significantly adds to the value of the new method described. Moreover, we confirmed that the differences have no impact when fabricating plantar orthoses, because we verified the fit of the orthoses to the cast and to the feet of participants, who said that both orthoses fitted well. However, we have to keep in mind that the new approach requires new skills from the technician, in particular in the field of data processing from 3D measurements and preparation of the 3D printing process.

Another disadvantage of 3D scanning reported in the literature is that it is very difficult to manipulate the foot and ankle while scanning [22]. However, we also overcame this disadvantage using photogrammetry, because obtaining the cast using phenolic foam allows ample possibilities for manipulating the foot. Although some authors have used photogrammetry to obtain facial prostheses and anatomical models [13–15], and others, such as Prajapati et al (2016), highlighted photogrammetry as the best method for scanning surgical samples because of the opportunity to obtain relatively accurate and high-quality data of objects [12], we found no studies analyzing the feasibility of using this technology to obtain positive casts of the foot to fabricate custom plantar orthoses. A comparison of 3D scans presented as a color map of deviations will give much more information than a point measurement with a caliper, but we have not used scanner technology in this work. It is also worth thinking about conducting research on the repeatability of measurement using photogrammetry in the future. Our study demonstrates that photogrammetry used with digital technology is a feasible tool for replicating custom positive casts of the feet suitable for fabricating plantar orthoses in the traditional manner. This process has several advantages over the traditional procedure of creating a plaster cast, including avoiding the use of plaster or other materials and providing a cleaner fabrication process. Moreover, casts made with plastic do not break, as frequently occurs with plaster casts, and plastic is also recyclable. Casts stored on a computer can be replicated indefinitely, facilitating replication of further orthoses and avoiding storage problems in the orthotics laboratory. In general, the digital process using photogrammetry allows us to save money, since with the rest of the digital processes, it is necessary to acquire a 3D scanner, while when using photogrammetry, only a mid-range mobile device is required, which we all have in our pockets nowadays. The rest of the process is similar, since we have not made the orthosis digitally. This work analyses whether the positive cast created is suitable for making thermoformed polypropylene orthoses in the orthopedic laboratory. Regarding the cost of manufacturing the orthosis with the help of the positive plastic cast, no information is provided on the average price of standard plantar orthoses and how photogrammetry would affect their final price because it is similar, but it has the advantage of management of manufacturing time when we use photogrammetry and being a cleaner process (and does not require an investment in space and infrastructure) as well as reproducible, as we have already explained.

Future lines of study should address the possibilities provided by this new method of smartphone image capturing and examine the most suitable materials for fabricating orthoses (depending on the health condition) for digital fabrication through additive manufacturing. They could also determine whether it is feasible to replicate this work using photos of participants' feet taken directly with a smartphone.

5. Conclusions

This work shows the possibility of obtaining positive cast of the foot, suitable for the creation of polypropylene plantar orthoses in a traditional way in the laboratory, in a digital way (positive casts printed in 3D) from the use of photogrammetry.

To do this, the currently validated methodology must be followed to obtain negative casts of the foot and use a phenolic foam, to later make multiple captures of it with the use of a mid-range smartphone, and finally, with the application of the photogrammetry and a 3D printer it is possible to digitize the process until obtaining the positive cast of the participant's foot.

The digital process is cleaner, safer and allows better time management. A professional can design the positive cast on a computer, without having to go to an orthopedic laboratory. This can be done in free slots in a practice. In addition, it will avoid the use of filling the negative cast with plaster, an essential process for obtaining the positive cast in the traditional way. Likewise, as it is a completely digital process, before the end of the working day, the created design can be sent to the printer and the positive cast would already be finished the next day, which allows to avoid the risk of the positive cast breaking if it is not completely dry. Therefore, this work shows that the use of photogrammetry allows the following advantages to be achieved with respect to the traditional method: optimal management of the professional's time, a cleaner and safer process and being equally suitable for the subsequent realization of the plantar orthosis.

In addition, this work opens a line of study, since, by obtaining a positive cast using photogrammetry, this will allow the complete digitization of the process with the consequent improvement of the process.

Author Contributions: Conceptualization, A.M.P.P., F.M.T., L.C.d.C.O., P.d.C.O., R.M.; methodology, A.M.P.P., R.M.; software, L.C.d.C.O., P.d.C.O.; formal analysis, A.M.P.P., R.M.; investigation, A.M.P.P., R.M.; resources, R.M.; writing—original draft preparation, A.M.P.P.; writing—review and editing, A.M.P.P., F.M.T., L.C.d.C.O., P.d.C.O., R.M.; supervision, R.M.; project administration, R.M.; funding acquisition, A.M.P.P., F.M.T., L.C.d.C.O., P.d.C.O., R.M. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the project “Research into the parametrisation and characterisation of processes for digital design and development of rigid plantar orthoses using additive manufacture”, co-financed by the European Regional Development Fund and the Extremadura Regional Government. Decree 113/2017, ORDER of 6 September 2017. Reference (IDA4-17-0017-2). This research also was funded by the Extremadura Regional Government and the European Regional Development Fund (ERDF) through a grant to the research group [code CTS020, reference GR18181, GR21077].

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper.

Data Availability Statement: Not applicable.

Acknowledgments: We thank Jane McGrath for assistance with the translation and final language review.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Health Organization. *Normas de Ortoprotésica. Parte 1: Normas*; USAID, WHO: Geneva, Switzerland, 2017.
2. Landorf, K.; Keenan, A.M.; Rushworth, R.L. Foot Orthosis Prescription Habits of Australian and New Zealand Podiatric Physicians. *J. Am. Podiatr. Med. Assoc.* **2001**, *91*, 174–183. [[CrossRef](#)] [[PubMed](#)]
3. Rencurel, C.; Puil, C.; Rouland, D.; Ceccaldi, E.; Boissonnot, V.; Bréard, T.; Janin, M. Ortesis plantares: Tipos, familias y conceptos. *EMC-Podol.* **2018**, *20*, 1–8. [[CrossRef](#)]
4. Panera Rico, E. Toma de molde en carga con control de presiones en pies pronados. Ph.D. Thesis, University of Sevilla. Facultad de Enfermería Fisioterapia y Podología, Sevilla, Spain, 2016.
5. Laughton, C.; Davis, I.M.; Williams, D.S. A comparison of four methods of obtaining a negative impression of the foot. *J. Am. Podiatr. Med. Assoc.* **2002**, *92*, 261–268. [[CrossRef](#)] [[PubMed](#)]
6. Rebouh, C. Principales materiales utilizados en las ortesis plantares. *EMC-Podol.* **2008**, *10*, 1–10. [[CrossRef](#)]
7. Dombroski, C.; Balsdon, M.E.; Froats, A. The use of a low cost 3D scanning and printing tool in the manufacture of custom-made foot orthoses: A preliminary study. *BMC Res. Notes* **2014**, *7*, 1–4. [[CrossRef](#)]

8. Telfer, S.; Pallari, J.; Munguia, J.; Dalgarno, K.; McGeough, M.; Woodburn, J. Embracing additive manufacture: Implications for foot and ankle orthosis design. *BMC Musculoskelet. Disord.* **2012**, *13*, 1–9. [\[CrossRef\]](#)
9. Aimar, A.; Palermo, A.; Innocenti, B. The Role of 3D Printing in Medical Applications: A. State of the Art. *J. Healthc. Eng.* **2019**, *2019*. [\[CrossRef\]](#)
10. Liaw, C.Y.; Guvendiren, M. Current and emerging applications of 3D printing in medicine. *Biofabrication* **2017**, *9*, 024102. [\[CrossRef\]](#)
11. Jin, Y.A.; Plott, J.; Chen, R.; Wensman, J.; Shih, A. Additive manufacturing of custom orthoses and prostheses—A review. *Procedia CIRP* **2015**, *36*, 199–204. [\[CrossRef\]](#)
12. Prajapati, S.; Madrigal, E.; Friedman, M.T. Acquisition, Visualization, and Potential Applications of 3D Data in Anatomic Pathology. *Discoveries* **2016**, *4*, e68. [\[CrossRef\]](#)
13. Salazar-Gamarra, R.; Seelaus, R.; Da Silva, J.V.L.; Da Silva, A.M.; Dib, L.L. Monoscopic photogrammetry to obtain 3D models by a mobile device: A method for making facial prostheses. *J. Otolaryngol. -Head Neck Surg.* **2016**, *45*, 1–13. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Mahmoud, A.; Bennett, M. Introducing 3-dimensional printing of a human anatomic pathology specimen: Potential benefits for undergraduate and postgraduate education and anatomic pathology practice. *Arch. Pathol. Lab. Med.* **2015**, *139*, 1048–1051. [\[CrossRef\]](#)
15. Turchini, J.; Buckland, M.E.; Gill, A.J.; Battye, S. Three-dimensional pathology specimen modeling using “structure-from-motion” photogrammetry: A powerful new tool for surgical pathology. *Arch. Pathol. Lab. Med.* **2018**, *142*, 1415–1420. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Benhamú Benhamú, S.; González Ubeda, R.; Martínez-Camuña, L.; Munuera-Martínez, P.; Guerrero Rodríguez, A. Protocolo de Toma de Moldes en Espuma Fenólica: Y Aplicativas sobre el Pie. *Rev. Española Podol.* **2004**, *15*, 184–194.
17. Doxey, G.E. Clinical use and fabrication of molded thermoplastic foot orthotic devices. Suggestion from the field. *Phys. Ther.* **1985**, *65*, 1679–1682. [\[CrossRef\]](#) [\[PubMed\]](#)
18. Levi Bensauly, E. Diseño Y Técnicas de Elaboración de la Ortesis Plantar. In *Ortopodología y Apararato Locomotor Ortopedia Pie y Tobillo*; Elsevier: Barcelona, Spain, 2003; pp. 123–146.
19. Ocello, M.; Lovotti, V. *Ortesis y Prótesis. Herramientas Para la Rehabilitación*, 1st ed.; Ediciones UNL: Santa Fe, Argentina, 2015.
20. Panera, E.; Domínguez, G. Toma de molde en carga con control de presiones en pies pronados. *Rev. Española Podol.* **2016**, *27*, 46–52. [\[CrossRef\]](#)
21. Song, E.; Yoon, S.; Son, H.; Yu, S. Foot Measurement Using 3D Scanning Model. *Int. J. Fuzzy Log. Intell. Syst.* **2018**, *18*, 167–174. [\[CrossRef\]](#)
22. Telfer, S.; Woodburn, J. The use of 3D surface scanning for the measurement and assessment of the human foot. *J. Foot Ankle Res.* **2010**, *3*, 1–9. [\[CrossRef\]](#)
23. Barrios-Muriel, J.; Romero-Sánchez, F.; Alonso-Sánchez, F.; Rodríguez Salgado, D. Advances in Orthotic and Prosthetic Manufacturing. *Materials* **2020**, *13*, 295. [\[CrossRef\]](#)
24. Jiménez, M. Rapid prototyping model for the manufacturing by thermoforming of occlusal splints. *Rapid Prototyp. J.* **2015**, *1*, 56–69. [\[CrossRef\]](#)
25. Mavroidis, C.; Ranky, R.G.; Sivak, M.L.; Patriitti, B.L.; Dipisa, J.; Caddle, J.; Gilhooly, K.; Govoni, L.; Sivak, S.; Lancia, M.; et al. Patient specific ankle-foot orthoses using rapid prototyping. *J. Neuroeng. Rehabil.* **2011**, *8*, 1–11. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Dessery, Y.; Pallari, J. Measurements agreement between low-cost and high-level handheld 3D scanners to scan the knee for designing a 3D printed knee brace. *PLoS ONE* **2018**, *13*, e0190585. [\[CrossRef\]](#)
27. Taha, Z.; Aris, M.A.; Ahmad, Z.; Hassan, M.H.A.; Sahim, N.N. A low cost 3D foot scanner for custom-made sports shoes. *Appl. Mech. Mater.* **2013**, *440*, 369–372. [\[CrossRef\]](#)

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.