Jurnal Keterapian Fisik
Vol. 9, No. 1, May 2024
https://doi.org/10.37341/jkf.v9i1.410

Original Research

A Comparative Analysis of Foot Orthosis Manufacturing Results Using the Gips Roll Casting and Custom 3D Scan Method

Prasetyo Catur Utomo[1], Atika Febri Anggriani[2*]

[1,2] Department of Orthotics Prosthetics, Poltekkes Kemenkes Surakarta, Indonesia

ABSTRACT

Background: *A musculoskeletal disorder that is often found is flatfoot. In handling various problems that occur in the foot, intervention can be given by using custom foot orthoses. The method often used in the process of making custom foot orthoses is the casting method. In recent years, advanced technology has continued to emerge and has really helped many manufacturers make foot orthoses with 3D scan tools and 3D printers. The aim of this research is to analyse the results of making foot orthoses using the cast roll casting method and a custom 3D scan.*

Methods: *The method used is experimental research with purposive sampling. The inclusion criteria were subjects with flat feet, and the exclusion criteria were subjects with deformities other than flat feet. The population was 38 people, and the respondent was 8. To determine the accuracy of measurements using statistical analysis with the Mann-Whitney test. Then the results of the two casting methods were fabricated and compared with measurements, as well as the efficiency of the foot orthosis manufacturing process using each method.*

Results: *The p value was 0.967 in the measurements with plaster roll media and 1.000 in the measurements with 3D scan media based on the respondent's original foot.*

Conclusion: *There is no significant difference between the two methods. So the 3D scan method can also be used as a method for developing custom foot orthosis fabrication processes to improve the development of science and technology in the field of prosthetic orthotics.*

ARTICLE HISTORY
Received: September 9th, 2024
Accepted: July 19th, 2024

KEYWORDS
foot orthoses, 3D print, 3D scan;

CONTACT
Atika Febri Anggriani
atikaanggriani07@gmail.com
Jl. Adi Sumarmo, Merten, Tohudan, Colomadu District, Karanganyar Regency, Central Java 57173.

Cite this as: Anggriani, A. F., & Utomo, P. C. (2024). A Comparative Analysis of Foot Orthosis Manufacturing Results Using the Gips Roll Casting and Custom 3D Scan Method. *Jurnal Keterapian Fisik*, *9*(1), 31–38. https://doi.org/10.37341/jkf.v9i1.410

INTRODUCTION

As time goes by and times progress, many problems are also encountered, one of which is in the health sector. One of the health problems that many people experience is musculoskeletal disorder (Siswiyanti et al., 2013). The Bureau of Labour Data Statistics (BLS) America provides reports that MSDs accounted for 29% compared to other occupational diseases.

Data related to musculoskeletal complaints in Europe in 2005 ranked first with a percentage of 38.1%. The prevalence of musculoskeletal diseases in Indonesia has been diagnosed by 11.9% of health workers, and based on the diagnosis, there are as many symptoms as there are 24.7% (Badan Penelitian Dan Pengembangan Kesehatan Republik Indonesia, 2018). Musculoskeletal disorders may occur in some areas of the human body, including the foot.

The musculoskeletal disorder that is often found is flat feet, or what is usually called flat feet. Flat foot is progressive, a condition where the arch of the foot is not visible on the medial side (Utomo et al., 2018). A flat foot is not only considered a static alignment problem of the ankle and foot but is also one of the causes of dynamic functional abnormalities of other lower extremities (Febri Yolanda Syafri, 2021).

Flat foot is a condition where the arch of the foot is not visible on the medial side (Utomo et al., 2018). Pes planus (flat foot) itself is a condition where the arches of the feet are not visible from birth and are buried in a lack of tissue (Zaidah, 2019). Flat foot patients require more muscle activity when walking due to a lack of medial longitudinal arches, which results in increased pressure on the second area of the metatarsal during the stance phase, causing the gait cycle in flat foot patients to be longer than for children who have a normal foot (Setyawan et al., 2023).

In flexible flat feet, the arch will be visible when the body is not bearing body weight (non-weight bearing), but will disappear (flatten) when bearing the weight of the body (weight bearing). In handling various problems that occur in the foot, intervention can be given in the form of using custom foot orthoses (Hajizadeh et al., 2020). FO can be used to prevent and relieve not only foot injuries but also hip disorders and musculoskeletal disorders in the knee (Akuzawa et al., 2016).

The method often used in the process of making custom foot orthoses is the casting method (Anggriani, 2020). In recent years, advanced technology has continued to emerge and has really helped many manufacturers make foot orthoses with 3D scan tools and 3D printers (Fantini et al., 2017). 3D scanning is the process of analysing a real-world object or environment to collect data on its shape and possibly its appearance (Rode et al., 2019).

In the context of rehabilitative health devices, 3D printing provides better fit and aesthetic improvement (Nugroho & Nurulita, 2019), for example, for the manufacture of 3D orthotics. A three-dimensional laser foot scanner to create the same shape, volume, length, width, and diameter as the patient's foot is the newest and most popular casting method for orthotics. Scanning only takes a few minutes and is fast.

Orthotists can design custom-made orthoses that offer maximum comfort with a perfect fit. The orthoses will be manufactured using high-tech software and machines. This can reduce the risk of dust or dirt while reducing clinical time. 3D scanning also offers higher accuracy than can be achieved by cast roll casting (Lee et al., 2014). In recent years, the use of 3D printing has become more popular in various industrial sectors, with the aerospace, military, automotive, medical, and construction industries increasingly taking advantage of it (Shah et al., 2019).

The various studies that have been carried out are research that only examines the casting process using the 3D scan method and casting using roll casts and has not examined in more depth the fabrication results using these two methods. So based on the background explained above, the aim of this research is to find a new way to make custom foot orthoses.

MATERIALS AND METHOD

The research method used is descriptive quantitative research with an analytical experimental research type. This research is comparative in nature, comparing 2 research groups, namely, group 1 using roll plaster media and group 2 using custom 3D scans. The population was 38 people. The sampling technique uses purposive sampling. The inclusion criteria were subjects with flat feet, and the exclusion criteria were subjects with deformities other than flat feet.

The respondent used in this research was 8 feet. Then the results of the two casting methods were fabricated and compared with the length and width dimensions, as well as the efficiency of the foot orthosis manufacturing process using each method. To determine the accuracy of measurements using statistical analysis with the Mann-Whitney test.

RESULTS

Based on the results of statistical tests using the Mann-Whitney test, it was found that the value of p = 0.967 in the comparison of FO measurements with plaster roll media and the value of p = 1.000 in the comparison of FO measurements with 3D scan media of the respondent's original foot. This explains that there is no difference in measurements in the comparison of FO with the cast roll fabrication method or 3D scan of the respondent's foot.

Table 1. Frequency distribution of gender, age, weight and height

Frequency	N	Min	Max
Gender			
Man	3		
Woman	1		
Age	4	20	21
Weight	4	45	63
Height	4	152	171

Table 2. Shapiro-Wilk data normality test results (N=24)

Treatment	Sig. Shapiro-Wilk	Information
Original Foot Size	0,000	Abnormal
FO cast roll	0,000	Abnormal
FO 3d scan	0,000	Abnormal

Based on the normality test using the Shapiro Wilk test, the three measurements, namely measuring the patient's original foot with an FO cast roll and an FO 3D scan on measuring foot length, MTPJ 1-MTPJ 5 diameter, and calcaneus diameter on the patient's original foot size, obtained a result of p <0.05, which shows that the data is not normally distributed. Because the data is not normally distributed, to determine the difference in measurements on the original foot using the cast roll FO fabrication method and 3D scan FO, a non-parametric test was carried out, namely the Mann-Whitney test, because it is data from two unpaired groups and the data is not normally distributed.

Table 3. Mann Whitney hypothesis test results for cast roll fabrication

	N	Mean Rank	Sum of Ranks
Original foot size	24	24.58	590.00
FO Gypsum roll size	24	24.42	586.00
Total	48		
Mann-Whitney U	286,000		
Z	586,000		
Asymp Sig. (2-tailed)	0.967		

Based on the results of statistical tests using the Mann-Whitney test, it was found that the value of p = 0.967 in the comparison of FO measurements with plaster roll media to the respondent's original foot. The p value is 0.967 (p > 0.05), which explains that there is no difference in measurements in the comparison of FO with the cast roll fabrication method and the respondent's foot.

Table 4. Mann Whitney Hypothesis Test Results 3D Scan Fabrication

	N	Mean Rank	Sum of Ranks
Original foot size	24	24.50	588.00
FO 3d scan size	24	24.50	588.00
Total	48		
Mann-Whitney U	288,000		
Z	58,000		
Asymp Sig. (2-tailed)	1,000		

Based on the results of statistical tests using the Mann-Whitney Test, it was found that the value of p = 1,000 in the comparison of FO measurements with 3D scan media on the respondent's real feet. The p value = 1.000 (p > 0.05) explains that there is no difference in measurements in the comparison of FO with the 3D scan fabrication method and the respondent's foot. From these two data points, it can be concluded that there is no significant influence, comparison, or difference in size between foot orthosis fabrication using roll plaster media and custom 3D scans on the respondents' feet. So Ha is accepted, meaning there is effectiveness in making custom foot orthoses using the 3D printing method.

Table 5. Results of the average value of original foot measurements, cast roll method, and 3D scan method

	Foot length (cm)		MTPJ Diameter 1-MTPJ 5 (cm)		Calcaneus diameter (cm)	
	Mean	Std deviation	Mean	Std deviation	Mean	Std deviation
*Foot*original	24.12	19.41	8.93	7.65	5.48	6.12
Cast roll	24.12	19.41	8.91	7.42	5.48	6.12
3d scan	24.43	16.75	8.87	7.35	5.48	6.12

Based on the data above, there is a difference in the average value between foot orthosis fabrication using roll plaster media and the respondent's original foot; in foot length, there is no difference; in the diameter of MTPJ 1–MTPJ 5, there is a difference of 0.02 cm; and in the diameter of the calcaneus, there is no difference. Meanwhile, in

the difference between the average values between fabrications using custom 3D scans and the respondents' original feet, there was a difference in foot length of 0.32 cm, in the diameter of MTPJ 1-MTPJ 5, there was a difference of 0.04 cm, and in the diameter of the calcaneus, there was no difference.

DISCUSSION

This research involved 4 respondents with a total of 8 feet: 4 right feet and 4 left feet. In this study, respondents were given foot orthosis fabrication treatment using roll plaster media and custom 3D scanning, intended to find out how efficient the use of scanning and 3D printing tools is in the foot orthosis fabrication process because respondents can position themselves during casting and fabrication by following the directions of the orthotist to remain static, especially when casting. In contrast to roll plaster media, if the respondent moves a lot, it can be restrained using his hands while waiting for it to dry.

In this study, respondents were asked to cast using roll plaster media once and scan using custom 3D scan media once. There is no repetition in this process. The use of modern and sophisticated scanning tools will make scanning easier, and there is no doubt about accuracy because, basically, the scanning tool has an object lock mode so that when the scanning tool is moved quickly, it is exposed to shock. This doesn't really affect the scanning process, but in custom 3D scans, using this tool requires patience and going slowly during the scanning process; this is done to prevent losing object locks (Lee et al., 2014).

When the tool loses the object lock, it requires it to return to the last position of the object lock until there is a green indicator on the laptop screen to continue the scanning process. According to research conducted by Lee et al., (2014) based on the results of this research, in comparing fabrication measurements using plaster roll media on respondents' feet, a value of $p = 0.967$ ($p > 0.05$) was obtained, which means that there was no difference in the positive plaster measurements compared to the respondents' foot measurements. In terms of the results of fabrication using plaster roll media, namely in terms of measurements, there is a slight difference between the results of the foot orthosis and the respondent's foot, namely a difference of 0.2 cm in the width measurement from the head of metatarsal 1 to the head of metatarsal 5 in one of the research subjects.

Measurements may differ due to human error by the researcher during the rectification process or the presence of space in the polyprophylene plastic against the positive cast during the moulding process. Meanwhile, the results of the comparison of the fabrication process using custom 3D scan media on the respondent's feet showed a value of $p = 1.000$ ($p > 0.05$), which means that there was no difference in the measurements of the 3D printed foot compared to the measurements of the respondent's feet. When casting using custom 3D scan media, there is no resistance, so the finger on the respondent's foot is often moved, which makes the results on the forefoot less appropriate. But because the scanning process using a custom 3D scan only takes around 3 to 5 minutes, the respondent is still willing to listen to instructions from researchers not to move too much.

Based on the results of the average value of the foot orthosis measurement (3D foot versus the original foot), it was found that the difference in the average value between the foot orthosis and the one fabricated using roll plaster on the respondent's original foot is: there is no difference in foot length; in the diameter of MTPJ 1–MTPJ

5, there is a difference of 0.28%; and in the diameter of the calcaneus, there is a difference of 5.48%; if accumulated, there is a difference of 5.76%. Meanwhile, in the average value difference between the 3D foot fabricated using a custom 3D scan and the respondent's original foot, there is a difference of 1.3% in the foot length; in the diameter of MTPJ 1–MTPJ 5, there is a difference of 0.56%; and in the calcaneus diameter, there is a difference of 0.56%. 5.48%; if accumulated, there is a difference of 7.34%. Where these results are obtained from the difference between the mean results of the foot orthosis and cast roll to the original foot and the 3D foot to the original foot, then these results are divided by the original foot data and then multiplied by 100%.

From the results of the comparative analysis of the two fabrication methods, it was found that the plaster roll method was superior in material selection compared to using the 3D scan method, which used PETG material. In terms of material, the use of polyprophylene plastic in foot orthosis fabrication using the cast roll method has advantages compared to the material used during fabrication using 3D scan and 3D print. This is because polyprophylene plastic has the advantage of being rigid but still flexible, so that research subjects can walk according to their phase.

However, the material used in the 3D scanning and 3D printing processes has very rigid properties, so it is necessary to select a more suitable material. Meanwhile, waste PETG 3D printing filament, if it still needs improvement, can be recycled so that it does not pollute the environment. As was done in research by Mikula et al., (2021) plastic recycling was found to be one of the main issues in environmental protection and waste management.

On the other hand, we also pay attention to the impact of the fabrication results using roll plaster media. There is a need to ask when the foot orthosis manufacturing process is finished whether the positive cast from the casting results will be discarded or reprocessed. If the positive impact ends in disposal, this can have a negative impact on the environment if we cannot manage the waste properly. According to research conducted by Henrique Geraldo et al., (2017) gypsum plaster waste (GPW) constitutes a large portion of the total construction and demolition waste produced by the community, which can pollute land and air resources.

The fabrication process using 3D scan and 3D print has several advantages compared to fabrication using the plaster roll method, including the respondent's comfort level when casting, the effectiveness of the time used, and cleanliness during the fabrication process. Respondents said that it was more comfortable when foot orthosis fabrication was carried out using the 3D scan method due to the efficiency of processing time and the cleanliness of the respondents' feet during the scanning process. Meanwhile, in terms of time, the time required for custom 3D scan media during the scanning process is only 3-5 minutes, the editing process takes approximately 1 hour, and the printing process takes approximately 3 hours, meaning the fabrication process can be done in time 1 day.

Meanwhile, for roll plaster media, it takes around 20–30 minutes for casting, then 1x24 hours to wait for the negative cast to be completely dry and ready for filling. It takes 30 minutes for the filling process, 1 hour for the rectification process, 30 minutes for the moulding process, 1 hour for chipping and trimming, and 30 minutes for fitting and finishing. So it can be concluded that the fabrication process using 3D scan 3D print has a shorter time duration compared to plaster roll media.

In terms of cleanliness, the level of cleanliness is far superior to fabrication using custom 3D scan media because it does not dirty the room or tools. 1 hour for the

rectification process, 30 minutes for the moulding process, 1 hour for chipping and trimming, and 30 minutes for fitting and finishing. So it can be concluded that the fabrication process using 3D scan 3D print has a shorter time duration compared to plaster roll media.

The analysis of the two fabrication methods shows that the two methods do not have a significant difference in size from the respondent's original foot size. In terms of comfort when casting, duration of fabrication time, and cleanliness, it is superior when using the 3D scan method, but in material selection, it is still superior to the fabrication process using roll plaster. So the 3D scan method can also be used as a method for developing the custom foot orthosis fabrication process to improve the development of science and technology in the field of prosthetic orthotics.

REFERENCES

Akuzawa, H., Imai, A., Iizuka, S., Matsunaga, N., & Kaneoka, K. (2016). Calf muscle activity alteration with foot orthoses insertion during walking measured by fine-wire electromyography. Journal of Physical Therapy Science, 28(12), 3458–3462. https://doi.org/10.1589/jpts.28.3458

Anggriani, A. F. (2020). Perbedaan Kecepatan Berjalan Penggunaan Rigid Medial Arch Support dengan Flexible Medial Arch Support pada Penderita Flat Foot. Jurnal Keterapian Fisik, 5(1), 28–32. https://doi.org/10.37341/jkf.v5i1.199

Badan Penelitian Dan Pengembangan Kesehatan Republik Indonesia. (2018). Laporan Riskesdas 2018 Nasional.pdf. In Lembaga Penerbit Balitbangkes (p. hal 156).

Fantini, M., De Crescenzio, F., Brognara, L., & Baldini, N. (2017). Design and rapid manufacturing of a customized foot orthosis: A first methodological study. Lecture Notes in Mechanical Engineering, 0, 457–467. https://doi.org/10.1007/978-3-319-45781-9_46

Febri Yolanda Syafri, R. F. U. (2021). Towel Curl Exercise Berpengaruh Terhadap Peningkatan Keseimbangan Statis Anak Dengan Flat Foot. Maternal Child Health Care, 3(3), 565. https://doi.org/10.32883/mchc.v3i3.1482

Hajizadeh, M., Desmyttere, G., Carmona, J.-P., Bleau, J., & Begon, M. (2020). Can foot orthoses impose different gait features based on geometrical design in healthy subjects? A systematic review and meta-analysis. Foot (Edinburgh, Scotland), 42, 101646. https://doi.org/10.1016/j.foot.2019.10.001

Henrique Geraldo, R., Pinheiro, S., Silva, J., Andrade, H., Dweck, J., Gonçalves, J., & Camarini, G. (2017). Gypsum plaster waste recycling: A potential environmental and industrial solution. Journal of Cleaner Production, 164. https://doi.org/10.1016/j.jclepro.2017.06.188

Lee, Y.-C., Lin, G., & Wang, M.-J. J. (2014). Comparing 3D foot scanning with conventional measurement methods. Journal of Foot and Ankle Research, 7(1), 44. https://doi.org/10.1186/s13047-014-0044-7

Mikula, K., Skrzypczak, D., Izydorczyk, G., Warchoł, J., Moustakas, K., Chojnacka, K., & Witek-Krowiak, A. (2021). 3D printing filament as a second life of waste plastics—a review. Environmental Science and Pollution Research, 28(10), 12321–12333. https://doi.org/10.1007/s11356-020-10657-8

Nugroho, A. S., & Nurulita, F. F. (2019). Hubungan Antara Pes Planus Dengan Keseimbangan Dinamis Pada Murid MI Nurul Karim Colomadu. Jurnal Keterapian Fisik, 4(1), 6–14. https://doi.org/10.37341/jkf.v4i1.120

Rode, S., Kadam, A., More, K., Fernandes, F., & Heber, G. (2019). Design And Development Of 3d Scanner.

Setyawan, D., Septiani, A., & Sari, K. (2023). Comparison For The Used Of Rigid Medial Arch Support And Flexible Medial Arch Support On Flat Feet Patients' Walking Speed. Journal of Prosthetics Orthotics and Science Technology, 2, 6–10. https://doi.org/10.36082/jpost.v2i1.957

Shah, J., Snider, B., Clarke, T., Kozutsky, S., Lacki, M., & Hosseini, A. (2019). Large-scale 3D printers for additive manufacturing: design considerations and challenges. The International Journal of Advanced Manufacturing Technology, 104, 1–15. https://doi.org/10.1007/s00170-019-04074-6

Siswiyanti, susilowati, & Pudjiastuti, S. S. (2013). Pengaruh Pemberian Edukasi Dan Medial Arch Support Terhadap Keseimbangan Dinamis Pada Kondisi Fleksibel Flatt Foot Anak Usia 8 S/D 10 Tahun. Jurnal Terpadu Ilmu Kesehatan, 521(2), 41–47.

Utomo, P. C., Setyawan, D., & Fathi, M. (2018). Pengaruh Penggunaan Medial Arch Support terhadap Penurunan Derajat Flat Foot Pada Anak Usia 8 - 12 Tahun. Jurnal Keterapian Fisik, Volume 3(No 2), 58–62.

Zaidah, L. (2019). Pengaruh Towel Curl Exercise Terhadap Peningkatan Keseimbangan Pada Anak Dengan Flat Foot Usia 4-5 Tahun melatih kelenturan , keseimbangan , dan kelincahan , dalam meningkatkan komponen tersebut kaki tidak tampak sejak lahir dan tertimbun jaringan lemak . Jurnal Ilmiah Fisioterapi, 2(02), 57–66.