

Impact of Stoma Baseplate Convexity on Tension and Compression Around the Stoma Site: A Finite Element Analysis

Review began 12/11/2023
Review ended 01/05/2024
Published 01/11/2024

© Copyright 2024

Waller et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Jonathan Waller¹, Philip Gowans², Suzanne Lord³, Katie McGill¹

1. Engineering, Kinneir Dufort Design Ltd., Bristol, GBR 2. Ostomy Care, Convatec Ltd., Deeside, GBR 3. Ostomy Care, Convatec Ltd., Lexington, USA

Corresponding author: Philip Gowans, philip.gowans@convatec.com

Abstract

For patients living with intestinal or urinary stomas, skin barriers play an essential role in protecting the peristomal skin and preventing peristomal complications. Convex baseplates press into the peristomal skin and are suitable for retracted stomas that do not protrude, peristomal skin with creases, folds, or dips, and stomas where frequent leaking can occur with flat pouching systems. However, there is a lack of data on the magnitude and location of tension applied to the abdomen by convex baseplates. We evaluated the impact of a range of convex baseplates applied to a simulated stoma site. A comparative finite element analysis investigation was conducted to evaluate the impact of eight different convex stoma system baseplates applied to an idealised flat abdomen, representing skin, subcutaneous tissue, and musculature layers. The baseplates considered had varying convexity with depths of 3.5 mm and 7 mm and internal structural diameters between ~30 mm and ~60 mm. The convex product range provided tension in the skin (maximum principal strain) and compression through the fat layer (minimum principal strain). Large differences in the locations and magnitudes of skin tension and fat layer compression were seen between the baseplates under analysis, with both the depth and diameter of convexity influencing the strain experienced across the abdominal topography. The results generated highlight the importance of having an appropriate range of convexity products available and selecting an appropriate option for use based on the stoma type and condition of the peristomal skin.

Categories: Gastroenterology

Keywords: wound care, ostomy care, urinary stomas, intestinal stomas, compression, tension, convexity, stoma, finite element

Introduction

Approximately one million people in the United States and 750,000 people in the European Union are estimated to be living with a stoma [1,2]. In ostomy care, a primary goal is establishing a secure and predictable seal between the peristomal skin and the baseplate of the stoma system [3]. Peristomal skin complications as a result of leaked effluent (e.g., peristomal moisture-associated skin damage) is common among people living with stomas and there are a number of solutions to improve this seal, from pastes and separate sealing components to convex baseplate designs that press into the peristomal skin [4,5]. While a flat baseplate design is typically suitable for patients with a budded stoma and flat peristomal skin, the curvature of a convex baseplate can better suit flush and retracted stomas that do not protrude, or peristomal skin with creases or folds [3,6]. For individuals who require convexity, a key challenge is selecting a correct fitting baseplate to maintain an adequate seal while minimising the risk of pressure injuries [3,5,6]. This challenge is compounded by significant patient-to-patient variation such as differences in skin folds, levels of abdominal fat, skin fragility, stoma size, and stoma protrusion [7].

There is a range of commercially available convex products with different characteristics to suit individual patient needs. An international consensus panel defined five fundamental convex product characteristics: depth, compressibility, flexibility, slope, and tension location [6]. Selecting appropriate values for these characteristics can allow a good seal to be generated while avoiding excess pressure on the peristomal skin [6]. However, there is a lack of data on the magnitude and location of tension applied on the abdomen by convex baseplates, limiting their effective and consistent implementation in clinical practice. To evaluate the effect of baseplate convexity on a stoma site with regard to skin tension and fat compression, we conducted a finite element (FE) analysis simulating the application of convex baseplates with different geometries and flexibilities to an abdomen, and compared the relative reactions in the abdomen.

Technical Report

Methods

Stoma System Baseplates

How to cite this article

Waller J, Gowans P, Lord S, et al. (January 11, 2024) Impact of Stoma Baseplate Convexity on Tension and Compression Around the Stoma Site: A Finite Element Analysis. Cureus 16(1): e52112. DOI 10.7759/cureus.52112

Eight stoma system baseplates (Convatec Ltd., Deeside, United Kingdom) with a range of inner diameters (28-58 mm) and depths (3.5 mm or 7 mm) were compared in this analysis (Figure 1). The baseplates are comprised of a flexible hydrocolloid layer that adheres to the skin and an injection moulded ethylene-vinyl acetate (EVA) component that provides structural support (Figure 2). The hydrocolloid layer has an inner region (A) that is cut to fit around the stoma and an unsupported outer region (E). The EVA component has an inside edge (B) that pushes into the abdomen and applies force to the peristomal skin, a cone-shaped region (C), and a flat region (D). The inner diameters of the baseplates were designed to apply force at different locations, with smaller inner diameters influencing the skin nearest the stoma (e.g., stomas that do not protrude above the skin) and larger inner diameters helping to smooth out and stabilise skin away from the stoma (e.g., skin with folds or creases).

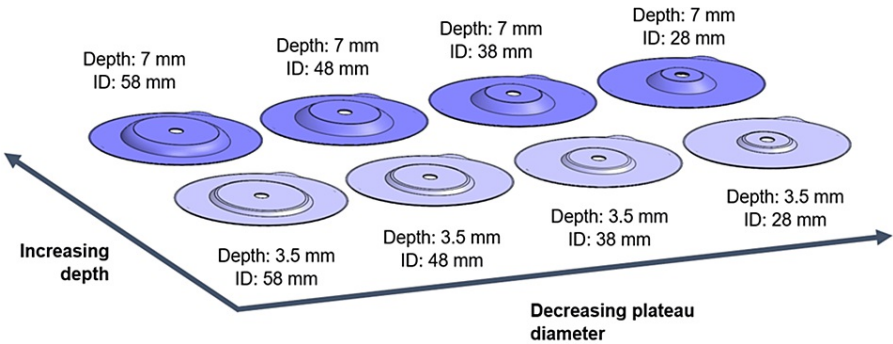


FIGURE 1: Range of stoma system baseplates
ID: inner diameter.

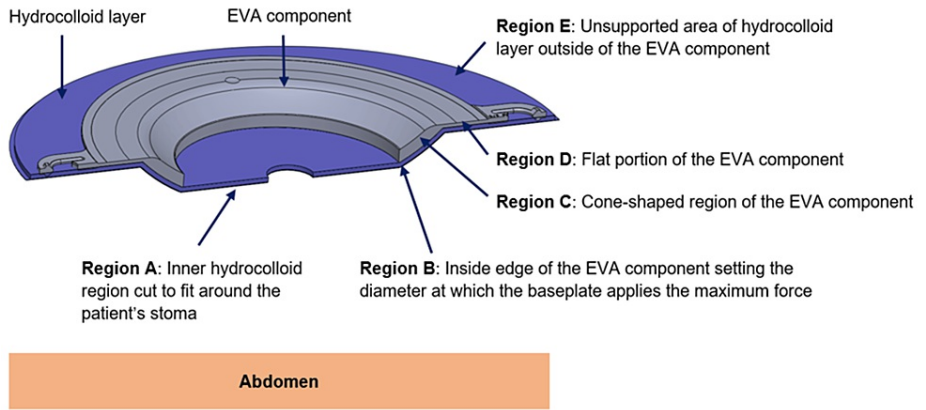


FIGURE 2: Key regions of stoma system baseplates
Cross-sectioned view of the 7 mm depth-38 mm diameter baseplate.
EVA: ethylene-vinyl acetate.

FE Analysis Model Setup

A literature review was conducted to identify the typical thicknesses of the abdominal layers (Figure 3), material properties (Figure 4), stoma surgical procedure, and the stoma pouching system application process. The geometries selected for the abdomen layers are illustrated in Figure 3. A controlled and neutral flat abdomen was selected as the best environment for this stage of the investigation as it allowed direct and controlled comparisons of the baseplate range. A more realistic or detailed abdomen may bias results according to the suitability of each product to the specific abdomen example being used.

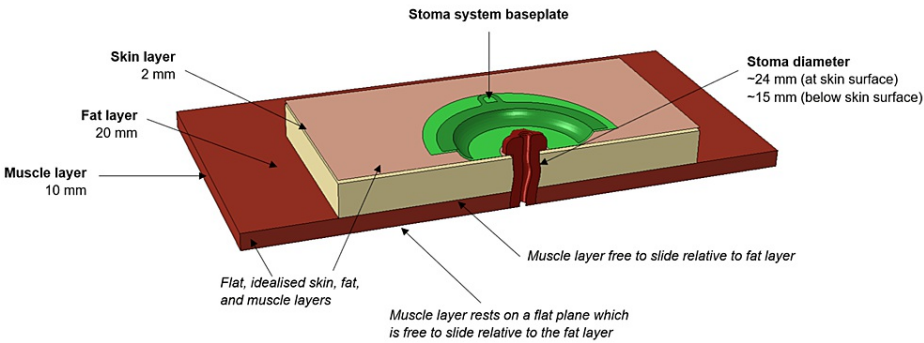


FIGURE 3: Abdomen model with idealised (flat) geometry and stoma baseplate for analysis

Information gathered from the literature review defined the parameters for skin [8-10], fat [8,10-12], and muscle [12,13] layers.

The material properties applied to each region of the model are illustrated in Figure 4. The literature review identified a wide range of linear elastic material properties that could be applied to represent the abdominal layers; the tissue stiffnesses for this study were selected from the lower end (lower Young’s modulus) as tissues exhibit softer behaviours under more quasi-static loading (i.e., during the application of an ostomy base plate). The material properties applied to the baseplates were taken from data supplied by Convatec Ltd. and the hydrocolloid adhesive and lamination film layers were simplified to a single part, with an appropriate composite stiffness applied. The key input parameters for the simulation model are summarised in Table 1.

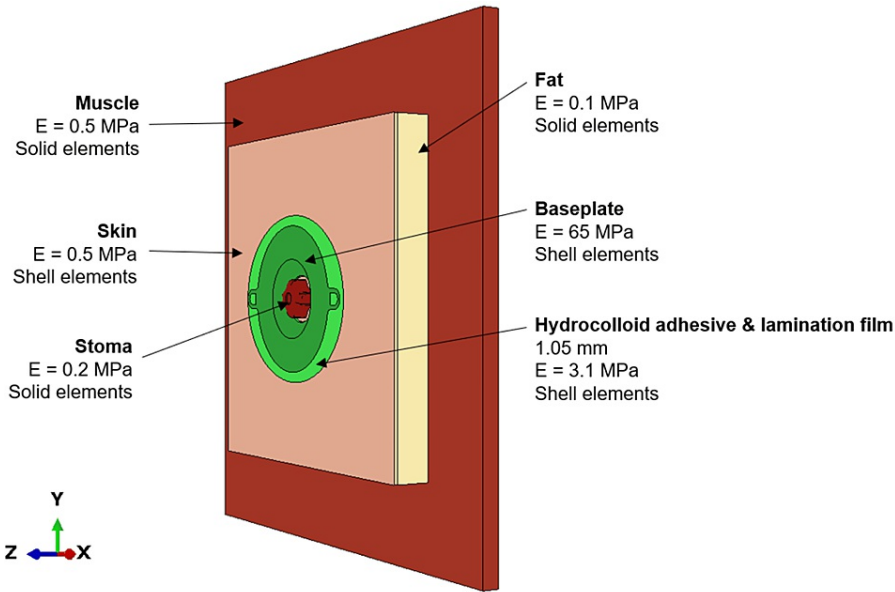


FIGURE 4: Material properties applied to each region of the flat abdomen model

Information gathered from the literature review defined the parameters for the skin [14], fat [15-17], muscle [15,17-19] layers, and the stoma [17].

Category	Selection for simulation
Software	Abaqus 2021
Material models	Skin layer: $E = 0.5 \text{ MPa}$, $\rho = 1000 \text{ kg/m}^3$ [14]
	Fat layer: $E = 0.1 \text{ MPa}$, $\rho = 900 \text{ kg/m}^3$ [15-17]
	Stoma: $E = 0.2 \text{ MPa}$, $\rho = 1100 \text{ kg/m}^3$ [17]
	Muscle: $E = 0.5 \text{ MPa}$, $\rho = 1100 \text{ kg/m}^3$ [15,17-19]
	Baseplate injection moulding: $E=65 \text{ MPa}$, $\rho = 900 \text{ kg/m}^3$
	Baseplate hydrocolloid layer: $E=3.1 \text{ MPa}$, $\rho = 900 \text{ kg/m}^3$
Study type(s)	3D dynamic explicit
Dimensions	Based on nominal Convatec CAD data and approximated abdomen geometries
Geometry features	Skin layer and baseplate layers modelled with shell elements
	Fat, muscle, and stoma modelled with solid elements
	3.5 mm depth baseplate EVA thickness: 1.4 mm at region C, 0.8 mm at region D (Figure 2)
	7 mm depth baseplate EVA thickness: 3.0 mm at region C, 0.8 mm at region D (Figure 2)
Other	Hydrocolloid layer 1.05 mm thick, combined with lamination film for all base plates
	Plate adheres to the skin on contact and is assumed to remain joined for the rest of simulation
	Stoma is tied to skin surface and fat layer
	Sliding is allowed between the fat and muscle layers
	Normal motion prevented at the base of the fat layer

TABLE 1: Key simulation parameters

CAD: computer-aided design; EVA: ethylene-vinyl acetate.

For ostomies, maturation (eversion) of the stoma requires suturing through the skin layer, the very top of the fat layer and through the intestinal wall which is pulled into contact with the skin layer [20]. This information was used in the construction of the simulation model to theoretically join the stoma to the skin layer. Further information on the extent of the bonding between the outside of the intestinal wall and the fat and muscle layers was not readily available.

Each baseplate product had a central hole cut to 26 mm, providing a minimum 1 mm border between the stoma and hydrocolloid layer. Each plate was applied to the abdomen in a three-step process: (1) a pressure resulting in 100 N of total force is gradually applied to the inner convex face of the EVA moulding on the baseplate. This aimed to approximate the initial location and application of the baseplate; (2) the force from step 1 is maintained and another 100 N force is gradually applied, distributed across the whole hydrocolloid layer, which aimed to approximate the pushing and smoothing steps; (3) all forces are released, allowing the assembly to relax and settle into the shape experienced when at rest with the baseplate adhered to the abdomen.

Output Parameters

Two sets of outputs, maximum principal strain (MaxPS) and minimum principal strain (MinPS), were generated based on key terminology identified in the literature pertaining to convexity in stoma care (Figure 5). MaxPS has been used to measure the outwards effect of the baseplate on the abdomen skin layer. Elements in the skin layer of the FE model are coloured according to the level of greatest tension or stretch experienced across each one. MinPS has been used to measure the downwards effect of the convex baseplate on the abdomen fat layer. Elements are coloured according to the peak level of compression (or squeezing).

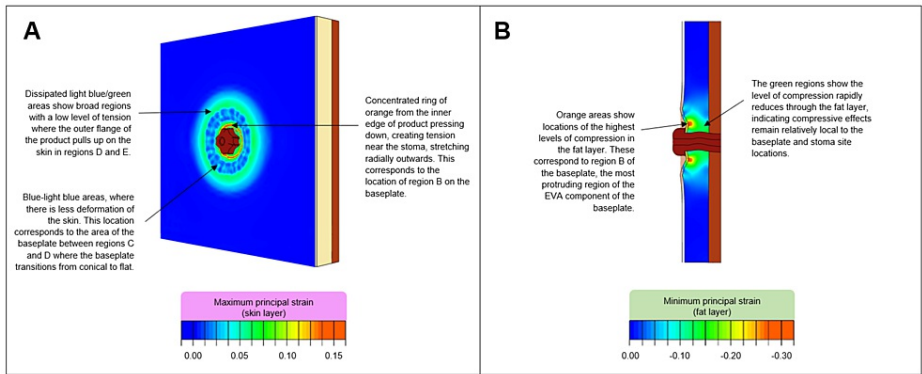


FIGURE 5: Annotated examples of (A) maximum principal strain response in the skin and (B) minimum principal strain response in the fat

Results

Comparative Outputs

Strain outputs for the baseplate range are shown in Figure 6, where MaxPS and MinPS represent skin tension and fat compression produced through convexity, respectively. For all baseplates, the magnitudes of the MaxPS and MinPS in the abdomen was found to depend on both the inner diameter and depth of convexity for each product. The greatest skin tension (MaxPS) and fat layer compression (MinPS) were found to be in the region directly under the inner diameter of the EVA baseplate (region B). These results show that the regions where greatest skin tension and fat layer compression occur vary based on the inner diameter of the EVA component for each product (region B). For all baseplates, the skin had areas of low level tension in the peripheral regions of the baseplates (regions D and E) created by the adhesive on the flange of the product lifting the skin. The 7 mm depth baseplates generated a higher level of central skin tension and fat layer compression than the 3.5 mm depth baseplates.

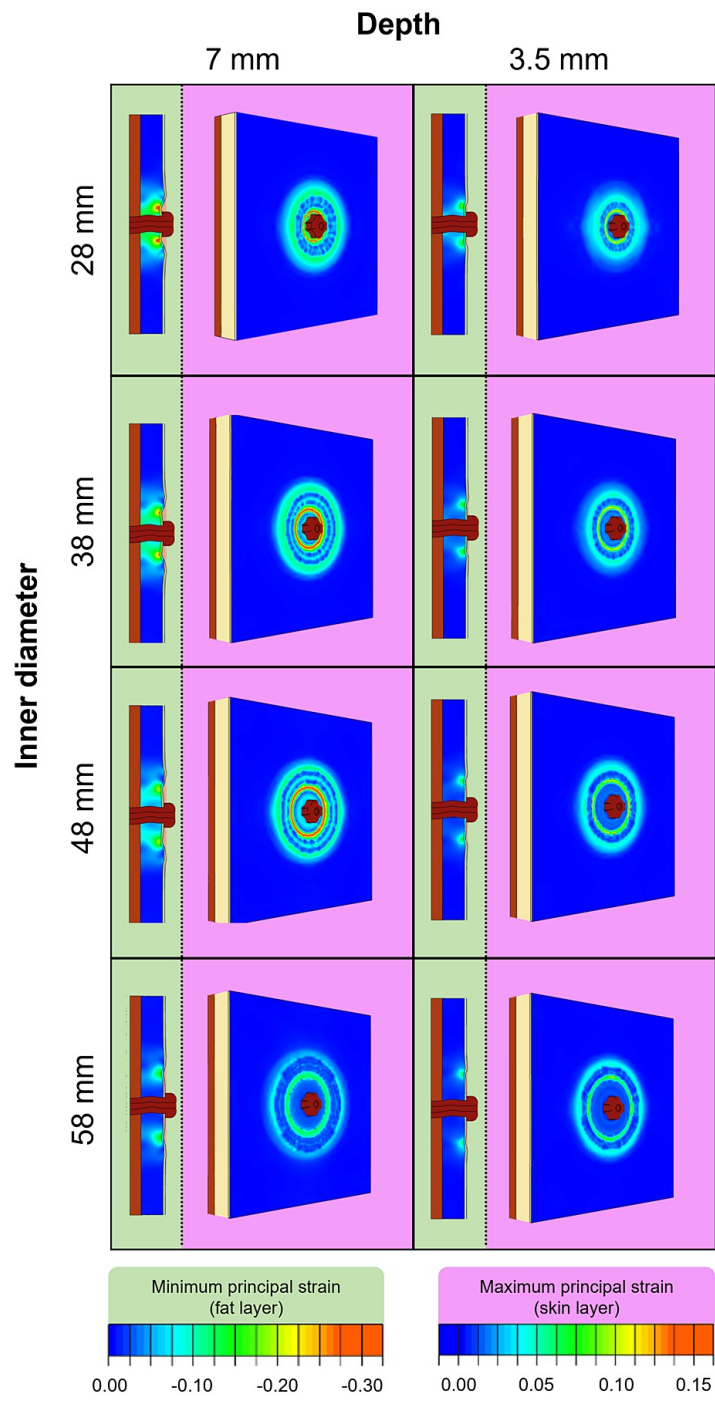


FIGURE 6: Comparative outputs for baseplate range after application to flat abdomen model

Maximum principal strain on the skin (pink columns) and minimal principal strain in the fat (green columns). ID: internal diameter.

Discussion

In this FE analysis, we simulated a range of stoma system baseplates on the abdomen to evaluate the effect of convexity on skin tension and fat compression. The simulations applied the baseplates to the same idealised flat abdomen, allowing for direct comparisons between the full baseplate range and for novel insights into the mechanics of convexity. FE modelling is an important tool that has been used to investigate pressure injuries and their prevention [21-23]. While an FE model has previously been used to visualise the biomechanics of the abdominal wall at different stoma locations [15], our study is the first to apply the method to baseplates around a stoma site.

Our findings show that in addition to generating compression in the fat layer, convex baseplates generate tension in the skin layer under region B. All baseplates produced the greatest skin tension and fat compression at the inner diameter of the EVA component (region B), corresponding to the peristomal skin being drawn outwards and the fat tissue being pushed down. Both the depth and inner diameter of baseplates were shown to affect the location and magnitude of the tension and compression experienced: the deeper baseplates (7 mm depth) produced greater strain than their flatter counterparts (3.5 mm depth) and the smallest diameter baseplates produced higher strains than the wider options. This demonstrates the complexity of the interaction between baseplate and abdomen, which is highly dependent on baseplate parameters. As such, there is value in having a range of convexity geometries.

While this work demonstrates the utility of the FE model in simulating the effect of different baseplate convexities on a peristomal abdomen under identical conditions, its clinical validity will need to be further investigated to explore if the simulated loadings and strains correlate with real-world measurements. For example, further refinement of the application process is warranted to better simulate realistic application pressures and sequences. Furthermore, future work could explore the effects of baseplate convexity on approximated real-world geometries instead of the idealised flat abdomen, compare convex products to nonconvex baseplates and between different manufacturers, as well as compare with moldable products.

Conclusions

The findings of this FE analysis illustrate the role of convexity in ostomy care and the value of having a range of baseplate geometries to address patient-to-patient variation in stoma type and peristomal skin. The convex product range under investigation produced skin tension and fat compression at different locations and magnitudes based on the depth and diameter of convexity. The FE method enables manufacturers and researchers to objectively compare stoma baseplate products and helps address the need for consistent reporting of product characteristics. Future work to explore the clinical utility of these findings is warranted.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Philip Gowans, Jonathan Waller, Suzanne Lord, Katie McGill

Acquisition, analysis, or interpretation of data: Philip Gowans, Jonathan Waller, Suzanne Lord, Katie McGill

Drafting of the manuscript: Philip Gowans, Jonathan Waller, Suzanne Lord, Katie McGill

Critical review of the manuscript for important intellectual content: Philip Gowans, Jonathan Waller, Suzanne Lord, Katie McGill

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue.

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** This study was funded by Convatec Ltd. **Financial relationships:** Jonathan Waller, Katie McGill declare(s) employment from Kinneir Dufort Design Ltd. Phillip Gowans, Suzanne Lord declare(s) employment from Convatec Ltd. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Acknowledgements

The authors would like to thank Nicola Pilmer (Convatec Ltd.) for the original concept of this work. Medical writing support was provided by Kenny Tran (Convatec Ltd.) in accordance with Good Publication Practice guidelines.

References

1. United Ostomy Associations of America. Living with an ostomy . (2023). Accessed: August 11, 2023; <https://www.ostomy.org/living-with-an-ostomy/>.
2. Access to Ostomy Supplies and Innovation: Guiding Principles for European Payers. EucoMed Medical Technology (Now, MedTech Europe), Brussels, Belgium; 2012. http://www.medtecheurope.org/wp-content/uploads/2015/09/2002012_MTE_Access-to-Ostomy-Supplies-and-Innovation-Guiding-....
3. Colwell JC, Stoa Davis J, Emodi K, et al.: Use of a convex pouching system in the postoperative period: a national consensus. J Wound Ostomy Continence Nurs. 2022, 49:240-6. [10.1097/WON.0000000000000874](https://doi.org/10.1097/WON.0000000000000874)

4. Nybaek H, Jemec GB: Skin problems in stoma patients . *J Eur Acad Dermatol Venereol*. 2010, 24:249-57. [10.1111/j.1468-3083.2010.03566.x](#)
5. Kwiatt M, Kawata M: Avoidance and management of stomal complications . *Clin Colon Rectal Surg*. 2013, 26:112-21. [10.1055/s-0033-1348050](#)
6. McNichol L, Cobb T, Depaifve Y, Quigley M, Smitka K, Gray M: Characteristics of convex skin barriers and clinical application: results of an international consensus panel. *J Wound Ostomy Continence Nurs*. 2021, 48:524-32. [10.1097/WON.0000000000000831](#)
7. Martins L, Andersen BD, Colwell J, et al.: Challenges faced by people with a stoma: peristomal body profile risk factors and leakage. *Br J Nurs*. 2022, 31:376-85. [10.12968/bjon.2022.31.7.376](#)
8. Derraik JG, Rademaker M, Cutfield WS, et al.: Effects of age, gender, BMI, and anatomical site on skin thickness in children and adults with diabetes. *PLoS One*. 2014, 9:e86637. [10.1371/journal.pone.0086637](#)
9. Gibney MA, Arce CH, Byron KJ, Hirsch LJ: Skin and subcutaneous adipose layer thickness in adults with diabetes at sites used for insulin injections: implications for needle length recommendations. *Curr Med Res Opin*. 2010, 26:1519-30. [10.1185/03007995.2010.481203](#)
10. Hong HH, Jo YC, Choi YS, Park HD, Kim BJ: An optical system to measure the thickness of the subcutaneous adipose tissue layer. *IEEE Sensors*. 2009, 695-8. [10.1109/ICSENS.2009.5398349](#)
11. Jain SM, Pandey K, Lahoti A, Rao PK: Evaluation of skin and subcutaneous tissue thickness at insulin injection sites in Indian, insulin naïve, type-2 diabetic adult population. *Indian J Endocrinol Metab*. 2013, 17:864-70. [10.4103/2230-8210.117249](#)
12. Kim J, Lim H, Lee SI, Kim YJ: Thickness of rectus abdominis muscle and abdominal subcutaneous fat tissue in adult women: correlation with age, pregnancy, laparotomy, and body mass index. *Arch Plast Surg*. 2012, 39:528-33. [10.5999/aps.2012.39.5.528](#)
13. Tahan N, Khademi-Kalantari K, Mohseni-Bandpei MA, Mikaili S, Baghban AA, Jaberzadeh S: Measurement of superficial and deep abdominal muscle thickness: an ultrasonography study. *J Physiol Anthropol*. 2016, 35:17. [10.1186/s40101-016-0106-6](#)
14. Kalra A, Lowe A, Al-Jumaily A: Mechanical behaviour of skin: a review . *J Mater Sci Eng*. 2016, 5:1000254.
15. Tuset L, López-Cano M, Fortuny G, López JM, Herrero J, Puigjaner D: Virtual simulation of the biomechanics of the abdominal wall with different stoma locations. *Sci Rep*. 2022, 12:3545. [10.1038/s41598-022-07555-z](#)
16. Arpaia P, Cuneo D, Grassini S, et al.: A finite element model of abdominal human tissue for improving the accuracy in insulin absorption assessment: a feasibility study. *Meas Sens*. 2021, 18:100218. [10.1016/j.measen.2021.100218](#)
17. Shigeta K, Kitagawa Y, Yasuki T: Development of next generation human body FE model capable of organ injury prediction. Proceedings of the 21st Annual Enhanced Safety of Vehicles, Stuttgart, Germany. National Highway Traffic Safety Administration, Washington, D.C.; 2009.
18. Shao Y, Zou D, Li Z, et al.: Blunt liver injury with intact ribs under impacts on the abdomen: a biomechanical investigation. *PLoS One*. 2013, 8:e52366. [10.1371/journal.pone.0052366](#)
19. Deeken CR, Lake SP: Mechanical properties of the abdominal wall and biomaterials utilized for hernia repair. *J Mech Behav Biomed Mater*. 2017, 74:411-27. [10.1016/j.jmbbm.2017.05.008](#)
20. Whitehead A, Cataldo PA: Technical considerations in stoma creation . *Clin Colon Rectal Surg*. 2017, 30:162-71. [10.1055/s-0037-1598156](#)
21. Xiao DZ, Wu SY, Mak AF: Accumulation of loading damage and unloading reperfusion injury--modeling of the propagation of deep tissue ulcers. *J Biomech*. 2014, 47:1658-64. [10.1016/j.jbiomech.2014.02.036](#)
22. Linder-Ganz E, Shabshin N, Itzhak Y, Yizhar Z, Siev-Ner I, Gefen A: Strains and stresses in sub-dermal tissues of the buttocks are greater in paraplegics than in healthy during sitting. *J Biomech*. 2008, 41:567-80. [10.1016/j.jbiomech.2007.10.011](#)
23. Sopher R, Nixon J, McGinnis E, Gefen A: The influence of foot posture, support stiffness, heel pad loading and tissue mechanical properties on biomechanical factors associated with a risk of heel ulceration. *J Mech Behav Biomed Mater*. 2011, 4:572-82. [10.1016/j.jmbbm.2011.01.004](#)