EXPLORING COMFORT AT THE PROSTHETIC-SOCKET INTERFACE FOR LOWER LIMB PROSTHETIC USERS



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EXECUTIVE SUMMARY

This report explores discomfort at the prosthetic-skin interface for lower-limb prosthetic users, focusing specifically on the socket as the primary point of contact between user and device. By evaluating current literature, benchmarking existing market products, and gathering primary data from prosthetic users, industry professionals, and practitioners, the report identifies design limitations in current socket solutions and highlights opportunities for new designs.

A user-centred research approach combined four data collection methods: an online survey (n=22) of lower-limb prosthetic users, a semi-structured interview with a professional swimmer and long-term prosthetic user, a contextual observation during gym and swim training sessions with the same participant, and a consultation with a Prosthetist and Prosthetic Technicians. This was supplemented by a benchmarking review and market analysis of ten existing socket, liner, and suspension products.

All four data sources suggested that heat and moisture are the largest contributing factors towards both general discomfort and skin conditions, with only one of 22 survey respondents reporting no skin conditions at all. Analysis found that the frequency with which users needed to adjust their prosthesis was a strong predictor of overall socket dysfunction, and that different suspension systems and liner materials were linked to distinct patterns of skin irritation. Benchmarking confirmed that no current product on the market successfully balances comfort, breathability, durability, and aesthetics simultaneously.

These findings inform design priorities - heat and moisture management, socket fit and load distribution, durability and waterproofing, aesthetics and customisation, and ease of cleaning. These priorities are a clear and evidence-based foundation for future concept development.



22 individuals with lower limb prosthetics surveyed

1 athlete and long term prosthetic user interviewed

1 athlete and long term prosthetic user observed

3 field specialists consulted (1 Prosthetist, 2 Prosthetic Technicians)

36 literature references

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AUTHENTICITY STATEMENT

This is to certify that to the best of my knowledge, the content of this report is my own work. This report has not been submitted for any other subject nor for any other purposes. I certify that the intellectual content of this report is the product of my own work and that all the assistance received in preparing this report and sources have been acknowledged.

Jordan Greensill
10/09/2026

AI USE STATEMENT

Generative AI (Claude, Anthropic) was used in the preparation of this report to assist in condensing written sections that exceeded the required word count while retaining their key content and clarity. AI was also used to provide guidance and direction on appropriate statistical analysis methods to research and implement in the JASP software for analysis of the survey data. All of the research, design, data collection, analysis, interpretation, discussions, implications and conclusions are my own. Any AI-assisted content was reviewed, curated, and edited by me prior to inclusion.

Jordan Greensill 

INTRODUCTION

An introduction to one of the biggest barriers to long-term comfort for lower-limb prosthetic users.

1.0 INTRODUCTION

The advancement of lower-limb prosthetics has restored mobility, independence, and improved the quality of life for millions of people worldwide with lower limb loss. Whilst modern technology has given way to improved function, the interface between the prosthetic socket and the residual limb continues to be one of the most challenging barriers to long-term comfort and true prosthetic integration (Liu et al., 2025). As the primary (and often only) point of contact between the prosthetic limb and the body, the prosthetic socket must distribute mechanical loads, whilst providing a secure, stable, and comfortable fit for extended periods of time and a variety of activities. Many users experience excessive heat and moisture entrapment, skin irritation, infection, and pressure-related discomfort (Diment et al., 2019; Kumetz & Cox, 2025; Zhang et al., 1996). These conditions can impact the duration for which a prosthetic can be worn, limit physical activity, and impact the user's relationship with the prosthetic, with socket fit shown to affect not only physical comfort, but also users' confidence in their prosthesis (Armitage et al., 2024).

Emerging technologies and advances in manufacturing technology, including 3D-scanning and 3D-printing, represent a new opportunity to reimagine the relationship between user and prosthetic (Dickinson et al., 2020; Shining 3D, 2023). Precedent already exists for bespoke, digitally manufactured prosthetic devices in other applications, such as 3D-printed partial-finger prostheses (Young et al., 2019). There is now opportunity to take designs beyond the limitations of uniform materials and traditional manufacturing procedures, creating bespoke prosthetic socket interfaces that respond to the anatomical and functional requirements of users on an individual-to-individual basis.

The aim of this project is to investigate discomfort at the prosthetic-skin interface for people using lower-limb prosthetics. By exploring the physiological, biomechanical, and current prosthetic design limitations that affect usability and comfort, the aim is to identify areas of opportunity for an improved prosthetic experience.



Figure 1 *- Visual of Project Structure*

BACKGROUND

A review of the physiological, mechanical, and thermal factors known to cause discomfort at the socket interface.

2.0 BACKGROUND

Discomfort at the interface between the prosthetic and residual limb is caused by an array of complex and nuanced mechanical, thermal, and physiological factors. Research suggests that there is a wide variety of unique stressors responsible for this, that differ from user to user. This makes diagnosis, treatment, and adjustment to prosthetics extremely challenging (Zhang et al.,1996;Culver, 2025; Limber Prosthetics, 2025). Due to the nature and limitations of prosthetic attachment technologies and the mechanics of the prosthetic socket, the residual limb experiences significant pressure and shear forces applied by the socket and liner during loading and gait. This friction force is the main factor responsible for skin irritation and breakdown in standard prosthetic sockets, and is common enough that dedicated clinical guidance exists specifically for managing it (EnableNSW, 2021; Zhang et al., 1996). To further complicate this sensitive interaction, the physical volume of the residual limb is not static. Fluid shifts caused by physical exertion, temperature, and even time of day, can cause the limb to fluctuate in size, which can drastically impact the quality of fit, and affect the comfort of the prosthetic within a single day of wear. Some users compensate for this volume change through sock-ply changes or manual adjustment (Sanders & Fatone, 2011; Hamzah et al., 2022).This intra-day fluctuation is well documented by prosthetic manufacturers (Vessl Prosthetics, 2026). Residual limb volume can also undergo more permanent volume shifts as the limb matures in the months following amputation (Aether Biomedical, 2026).

Thermal and moisture-related discomfort is also a common and well established cause of issues. Research by Diment et al. (2019), establishes a clear and measurable relationship between perceived thermal discomfort, and residual limb skin temperature during exercise. This is reinforced by physiological factors specific to amputation itself, as a reduced skin surface area directly inhibits the body's capacity to naturally thermoregulate. The body naturally compensates by sweating more heavily than what would be typical. This increased sweating is often localised to the residual limb, but for some may affect the entire body, in a condition is known as hyperhidrosis (Pivotal, 2021; Henson, 2020). Furthermore, as this surplus of compensatory sweat is often generated inside an enclosed, non-breathable socket environment, the resulting moisture and sustained heat can create conditions conducive to skin maceration, contact dermatitis, and fungal infection (Munoz et al., 2008; Kumetz & Cox, 2025). In severe or prolonged cases, this can contribute to ulceration, and bacterial or fungal infections that require clinical intervention (Highsmith et al., 2016). These skin conditions are extremely significant as they can force reduced wear time, which strips independence and mobility from the user. Common clinical recommendations include moisture-wicking liner socks, antiperspirant application, and stricter hygiene routines. These largely function as workarounds rather than addressing the cause of the problem, being the socket itself (Casson, 2025; Van Den Boom, 2019).

There are a variety of prosthetic socket types and suspension devices that each attempt to reduce these effects. Anatomical Suspension (Figure 2), Suction (Figure 3), Pin (Figure 4), Vacuum-assisted (Figure 5), and Strap Suspension systems (Figure 6) all offer trade-offs between retention, mechanical load distribution, and donning/doffing (putting on and taking off) practicality (Casson, 2024). Hard-shell sockets and soft-socket constructions differ in their respective approaches toward rigidity, support, and comfort (Orthotics Ltd, 2025). Armitage et al. (2024) also finds that the importance of the prosthetic socket extends even beyond physical characteristics, inspiring a sense of identity, confidence, and community within many users. The link between prosthesis and identity has also been voiced by elite athletes such as Paralympic swimmer Timothy Hodge, who described the custom flame design on his prosthetic socket as "part of his identity," saying the design has made him more recognisable and memorable (Lane, 2026).



“It became sort of a part of my identity [so I’ve] continued on since then with the flame design.”

Figure 2 *- Timothy Hodge OAM and his custom flaming prosthetic (Lane, 2026)*

As 3D scanning and additive manufacturing technologies continue to become increasingly advanced and accessible, the ability to tailor sockets to individual limb geometry via digital mediums rather than labour intensive manufacturing processes draws nearer and more probable (Dickinson et al., 2020; Shining 3D, 2023). Simultaneously, new monitoring technologies, improved sensors, and more advanced metrics aim to make previously unmeasurable and unaccounted variables, such as localised pressure and moisture, measurable in real time (Liu et al., 2025). Despite these advancements, very few existing solutions address mechanical fit and thermal management as two facets of the same problem, and instead respond to both individually, often for less effective results and poorer experiences for users. This represents a clear opportunity for a new approach to the design of prosthetic sockets, leveraging new technologies for improved user experiences.

ANATOMICAL SUSPENSION (SELF-SUSPENDING)

Anatomical suspension takes advantage of the natural shape of the residual limb, such as the femoral condyles, to mechanically retain the socket without a locking mechanism, relying instead on a close contoured fit. The mechanism for this type of socket usually relies on a compliant foam liner that can deform to fit over the joint, and then friction fit into the carbon fibre socket. This type of suspension is typically seen in knee disarticulations, also known as through-knee amputations, or transarticular amputations, as the femur is left fully intact (MedEast, 2025).



Figure 3 *- Transarticular Amputation with Anatomically Suspended Prosthetic (Northcliff Orthopaedic, 2023)*

SUCTION SUSPENSION

Suction Suspension relies on an airtight seal between a flexible silicone liner and the socket wall. A one-way valve is usually integrated into the socket to allow for the expulsion of air and moisture when the socket is donned. This creates negative pressure that holds the prosthetic in place (Casson, 2024).

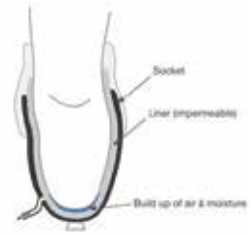


Figure 4 *- Suction Socket (Blatchford Mobility, 2019)*

PIN SUSPENSION

Pin suspension consists of a silicone, gel, or textile liner fitted with a distal pin that is received by a locking mechanism at the base of the socket. This creates a secure and robust mechanical connection that is simple to don and doff (Ottobock Care, 2023).



Figure 5 *- Pin Locking Liner (Silipos, 2026)*

VACUUM-ASSISTED SUSPENSION

Vacuum-assisted suspension applies the same principles as suction suspension, utilising a mechanical or electronic pump to actively maintain negative pressure throughout the socket. Unlike suction suspension, the active vacuum adjust for residual limb volume fluctuation dynamically, where passive suction alone cannot (Casson, 2024).



Figure 6 *- Vacuum-Assisted Socket (Ossur, 2024)*

STRAP SUSPENSION

Strap or Cuff suspension secures the socket using an external strap, belt, or cuff around the limb or torso. This is typically used as an auxiliary suspension method alongside other primary systems (MedEast, 2025).

*Bone-anchored (osseointegrated) systems represent an alternative attachment method that bypasses the socket interface entirely, and are thus not being investigated (Atallah et al., 2018)

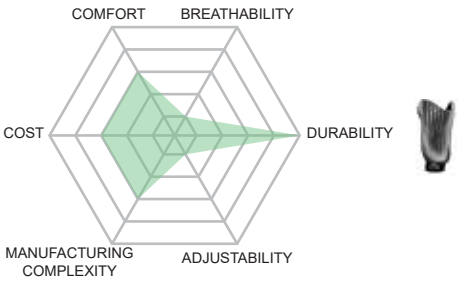


Figure 7 *- Strap Suspension (Knitrite, 2025)*

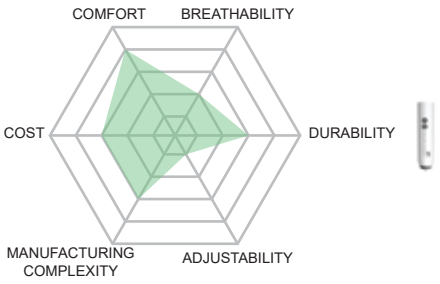
BENCHMARKING

An analysis of ten existing market products, evaluating a variety of factors.

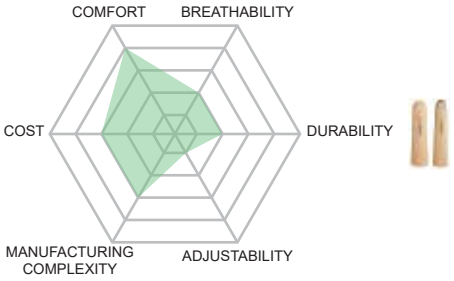
Traditional Carbon Socket



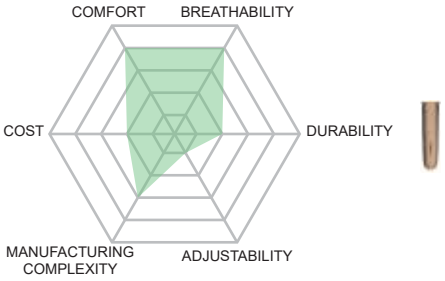
Össur Iceross Liner



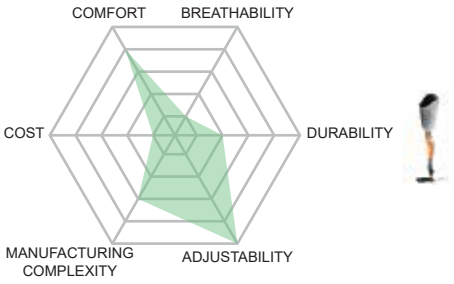
WillowWood Alpha Liner



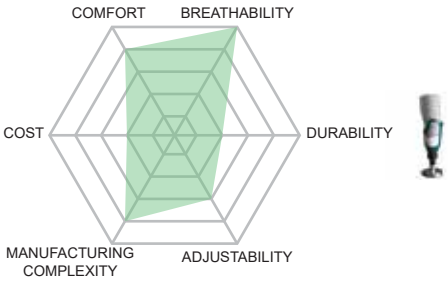
Blatchford TACT Socket



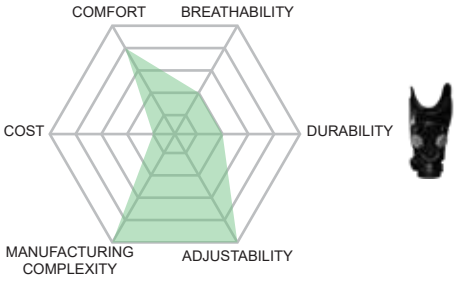
ProsFit 3D Printed Socket



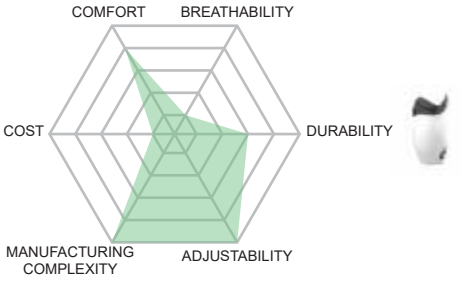
WillowWood One System



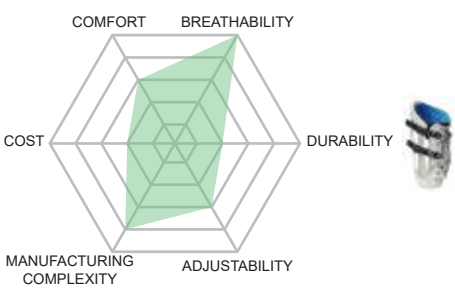
Quorum Quatro



Augo® 3D-printed TT Socket



Martin Bionics Socket-less Socket



Infinite Socket

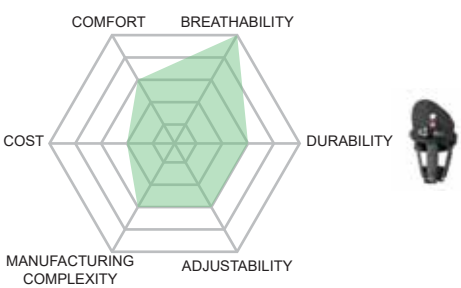


Figure 8 *- Radar Graph Benchmarking of Market Products*

3.0 BENCHMARKING

Traditional carbon-fibre sockets are reinforced to be the benchmark for durability, scoring highest of all products reviewed in the category. However, this comes at the direct expense of breathability, where carbon-fibre consistently scores the lowest across all traditional rigid-shell designs. Liner-based products, such as the Össur Iceross and WillowWood Alpha, prioritise comfort over durability and adjustability. It is important to consider, however, that these products are interface layers rather than structural components, and neither meaningfully improve breathability when paired with the rigid socket. The analysis shows a clear divide between mechanically and breathability oriented solutions. Products such as the ProsFit 3D Printed Socket, Quorum Quatro, and Augo 3D-printed TT Socket achieve high adjustability through 3D-printed, patient-specific geometry, but this consistently coincides with increased manufacturing complexity, and does not translate into meaningfully improved breathability. Designs focused on improved breathability, such as the Martin Bionics Socket-less Socket, WillowWood One System, and Infinite Socket, achieve the highest breathability scores in the review. This is largely achieved by removing or minimising the enclosed rigid shell, a trade-off that significantly impacts durability and cost advantages of conventional sockets, and increases manufacturing complexity. No single product in the review simultaneously scores highly on comfort, breathability, and durability, while maintaining low manufacturing complexity.

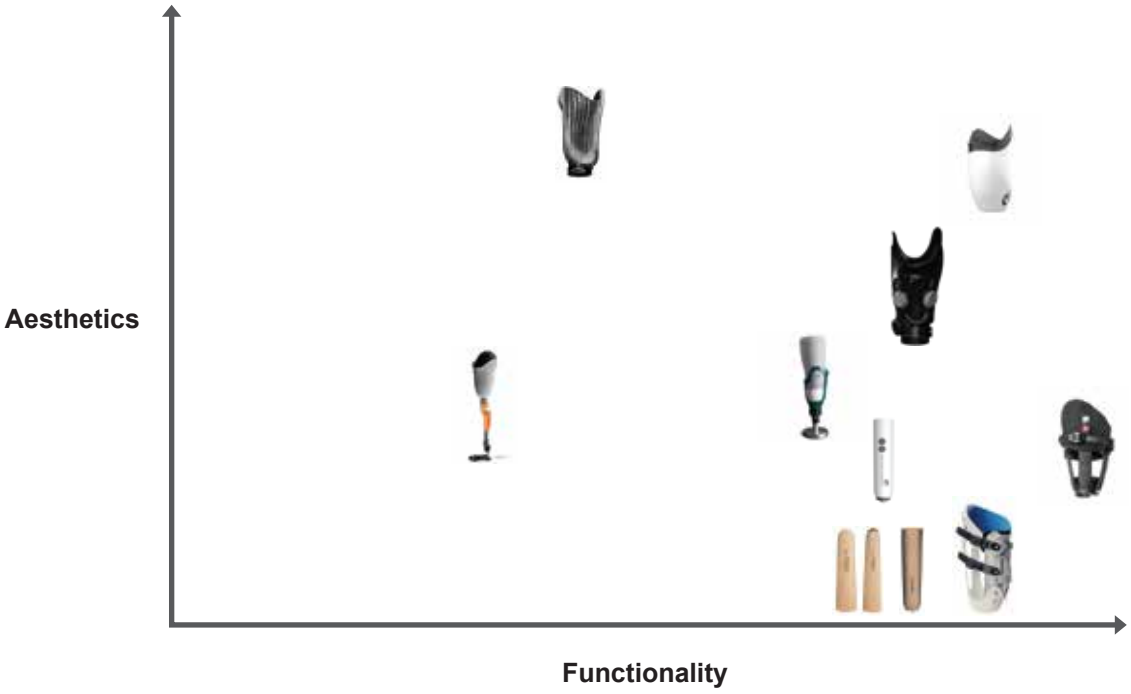


Figure 9 *- Product Aesthetics vs Functionality*

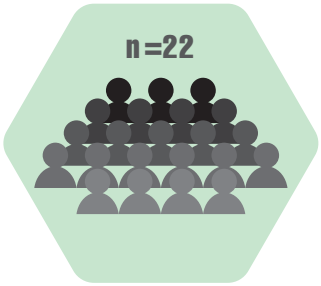
Figure 8 shows that highly functional, breathable, and adjustable designs (e.g. the Infinite Socket, Martin Bionics Socket-less Socket) tend to score lowest on aesthetics. The traditional carbon socket, despite its lower functional score, ranks well for aesthetic appeal due to its smooth, low-profile finish. Only the Augo 3D-printed TT Socket and Quorum Quatro approach a balance of both functionality and aesthetics. This suggests that current market solutions approach aesthetics as a secondary or tertiary priority rather than complementary to function as a design objective. There is no single product in the review that successfully integrates high breathability and comfort with the durability, manufacturing simplicity, and the aesthetic refinement of a traditional socket. There is definite opportunity for a product that can bridge the gap between form and function.

RESEARCH

Collecting real data to triangulate the lived experience of prosthetic discomfort.

4.0 RESEARCH

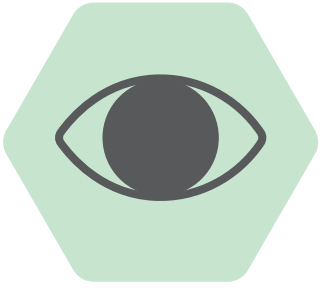
As the relationship between user and prosthetic is deeply personal, a user-centered research approach is imperative to fully encapsulate and accurately represent the experiences of users, particularly their comfort at the prosthetic socket interface. A combination of quantitative and qualitative methods were used to gather both broad user perspectives and detailed accounts of individual experiences, alongside insight from industry practitioners. Data collection was achieved via four mediums; an online survey, semi-structured interviews, contextual observations, and an informal workshop discussion witha Prosthetist and Prosthetic Technicians with combined 30+ years of experience.



An online survey was deployed to collect responses from a broad population of lower-limb prosthetic users. The survey focused on participants' prosthetic use, areas of discomfort, and factors that abstract from their experience of wearing a prosthesis. The survey collected data from a large number of participants, allowing experiences to be compared across users. This will allow for the analysis of common trends and themes. The survey was deployed to a variety of populations, including members of the Australian Para Dolphins Swim Team, as well as Facebook and Reddit communities for amputees and prosthetic users. This breadth of audience aims to ensure that the experiences and input of users with different levels of activity and varying lifestyles are accounted for in the data. The data includes high-performance athletes' experience with prosthetics, while also reaching participants who use their prostheses in everyday environments.



A semi-structured interview was conducted with a competitive swimmer and long-term lower-limb prosthetic user. The interview explored the topics of daily use of their prosthesis, physical activity, socket comfort, fit, pressure, sweating, skin issues, durability, previous poor experiences, and barriers of the current prosthetic. A semi-structured format was selected as it ensured information was collected for the vital topics, whilst allowing for other experiences and potentially valuable information to instead present through natural conversation. The interview was audio recorded and transcribed for further analysis.



Additionally, an in-situ observation was conducted during a gym and swim training session with the same participant. Observing prosthetic use within familiar activities allowed behaviours and interactions to be recorded as they would normally occur. The gym portion of the observation focused on how the prosthesis was used during exercise. Visible perspiration was also noted and residual-limb temperature was monitored at consistent intervals throughout the hour-long session using a non-contact infrared thermometer. A baseline temperature was recorded prior to the commencement of the gym session, and four additional residual-limb surface temperature measurements were documented during the session, all of which requiring the prosthetic limb to be temporarily removed. During the swim session, the observation focused on the participant's dryland activation prior to the session, prosthesis removal and storage, and routine post-swim. Environmental conditions and observable effects on the prosthetic were also documented.

An informal workshop observation and discussion was conducted with a Prosthetist, and two other Brisbane-based Prosthetic Technicians, each with over ten years of industry experience. This session took the form of an open conversation over the course of an hour, during which the technicians demonstrated their current socket fabrication workflow and discussed the practical challenges of manufacturing, material selection, and the adoption of digital technologies such as 3D scanning and printing.



Figure 10 *- Technicians hand-shaping a 'check socket' over a plaster mould during the visit to the workshop*



Figure 11 *- A completed prosthetic socket featuring a custom graphic, photographed during the tour*

The use of multiple data collection methods allows for triangulation of trends and more thorough examination of authentic prosthetic use and experiences from a variety of valuable perspectives. The survey provides broad comparative data, whilst the interview and observation allow for an authentic and unfiltered lens through which behaviour and prosthesis use within day-to-day life can be ascertained more accurately and objectively. The workshop discussion with the Prosthetist and Prosthetic Technicians further complements this user-centred data, with the industry-practitioner perspective offering technical insight into current fabrication practices, material constraints, and barriers to adopting new manufacturing technologies. Together, these four methods form the basis for identifying common experiences, behaviours, pain-points, and areas of opportunity that can potentially make meaningful improvements to the user experience.

ANALYSIS + FINDINGS

Determining the most significant and interconnected causes of discomfort and impacted skin health.

5.0 ANALYSIS + FINDINGS



Survey responses were exported and analysed using the free and open-source software JASP (JASP Team, 2024). According to *Analyzing and Interpreting Data From Likert-Type Scales* (Sullivan & Artino, 2013), descriptive statistics (N, mean, SD, median) and Spearman's rank-order correlation (rs) should be used to identify and quantify relationships between the survey questions that yield Likert-scale data. This allows for information to be compiled and clustered for easier breakdown and analysis.



The interview with the prosthetic user was transcribed and coded, sorting information into five major themes. The five themes are; thermal comfort/moisture management, skin health, socket fit, durability/maintenance, and activity/independence. These were then compared to the survey's quantitative trends to identify if there was consistency.



The observation session with the prosthetic user, as well as the visit to the prosthetic socket manufacturer included digital recordings, which were converted into a transcript describing the events, alongside the quantitative thermometer data recordings.

5.1 RESULTS

Of the 22 survey respondents, only one reported experiencing no skin conditions at all, meaning 95% of participants have encountered at least one form of skin irritation, infection, or breakdown as a result of prosthetic use. Thermal discomfort and moisture management were mentioned above all else in all data sources. In the survey, heat/perspiration was the most frequently reported cause of discomfort across every single prosthetic suspension system. Moisture accumulation correlated very strongly with both heat discomfort; $rs(20) = .72$, $p < .001$, and skin problems, $rs(20) = .63$, $p = .002$.

The interviewed prosthetic user also identified sweating as their primary and most limiting issue, stating that they believe it is "the cause of everything else," and described their anatomically suspended socket as retaining odour and moisture. During the gym-session observation of the same participant, residual-limb temperature rose from 36.5°C pre-session to 36.8°C during exercise and remained elevated at 36.8°C across three subsequent readings, alongside a visible increase in sweat when compared to a pre-session baseline.

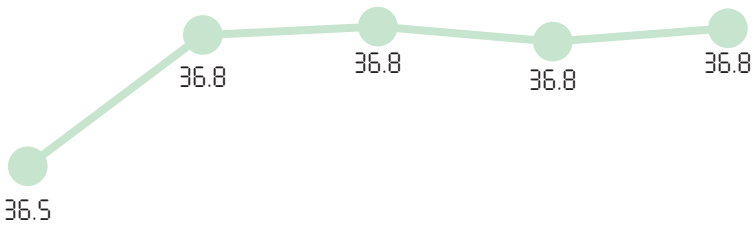


Figure 12t *- Residual limb temperatures during observation*



Figure 13 *- Residual limb temperature measurement*

The swim-session observation also provided a useful and unexpected insight. Despite the winter conditions and time of day (the observation was conducted at roughly 10am), the prosthetic became extremely hot to the touch whilst left leaning next to the pool for the duration of the swim session (roughly 1.5 hours). This temperature increase was a result of direct sun exposure alone, to the point of triggering a thermal failsafe in the electronically controlled hydraulic mechanism in the Ottobock Genium X4 prosthetic. While the electronic response sits outside the scope of the investigation, this indicates that the darkly coloured carbon-fibre/resin outer shell of the socket absorbed a massive amount solar radiation. This is a non-insignificant external heat load secondary to the internal heat generated by activity, the body, and friction. Additionally, the interview supplies a physiological explanation for increased sweating and struggle to regulate temperature within the socket (hyperhidrosis). This is a pattern that the survey shows statistically and the observation demonstrated directly.

The number of skin conditions, as a metric, correlates with perceived socket temperature and heat retention more closely than mechanical load. The strongest relationship in the entire dataset was the link between survey respondents who reported their limb becoming noticeably hot, and number of skin problems; $r_s(20) = 0.74$, $p < .001$. The count of distinct skin conditions was not the original intention of the interview question, but was actually a very strong and useful metric of comparison.

Skin issue count correlated with friction discomfort; $r_s(20) = .68$, $p = .001$, pressure discomfort; $r_s(20) = .61$, $p = .002$, and moisture accumulation; $r_s(20) = .60$, $p = .003$. This indicates that respondents experiencing more frequent mechanical and thermal discomfort were also accumulating a wider range of skin conditions, and not necessarily just more severe symptoms. This corroborates the participant's account from the interview, who complained of a current fungal infection. This was attributed to moisture accumulation, alongside a history of blisters and chafing.

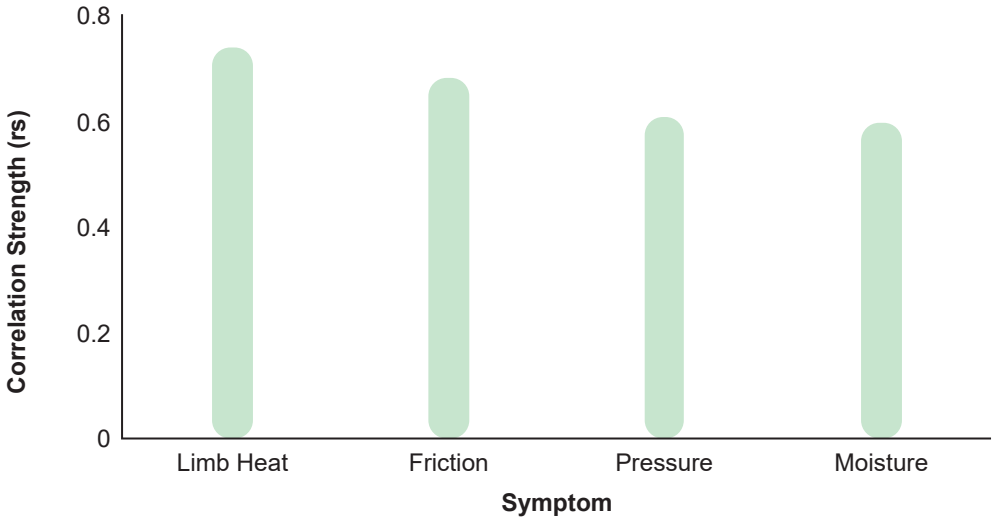


Figure 15 *- Symptom correlation strength with Skin Conditions*

Also significant, is that there was correlation between the skin condition reported, and the type of socket liner the user wears. Pressure sores and rashes were reported exclusively by foam liner users (40% each). Neither of these conditions were reported by any silicone liner user. Conversely, ingrown hairs were reported only among silicone liner users (19%), which was echoed by the Prosthetist and workshop staff who indicated that suction suspension systems (commonly paired with silicone liners) are strongly associated with ingrown hairs. Excessive sweating and redness were reported at similar rates across both liner types (75-80%). This suggests that thermal or moisture problems persist regardless of liner material. There were also patterns present amongst the suspension systems. Fungal infection was most common among anatomical suspension users (44%) and barely present in suction and vacuum-assisted suspension systems (14% and 0% respectively). Blisters and chafing were similarly concentrated in anatomical suspension users (44% each). By combining comfort, pressure, friction, heat, skin problems, limb-heat frequency, moisture, and adjustment frequency into a single index, it was shown that four of the five worst-performing individual respondents in the entire dataset used anatomical suspension. Carbon Fibre paired with anatomical suspension was, on average, the worst-performing combination of any pairing. Pairings with less than two respondents were excluded from this measure.

How often a participant needed to adjust their prosthesis during the day was also a broadly connected variable in the survey, correlating with nearly every other discomfort measure. Adjustment frequency was associated with friction discomfort; rs(20) = .65, p = .001, heat discomfort; rs(20) = .64, p = .001, activity-related impact on socket fit; rs(20) = -.56, p = .006, pressure discomfort; rs(20) = .54, p = .010, skin problems; rs(20) = .50, p = .017, and typical day-to-day comfort itself; rs(20) = -.48, p = .023. This also points to the number of times a participant reported adjusting their prosthetic per day as being a good indicator of general socket dysfunction.

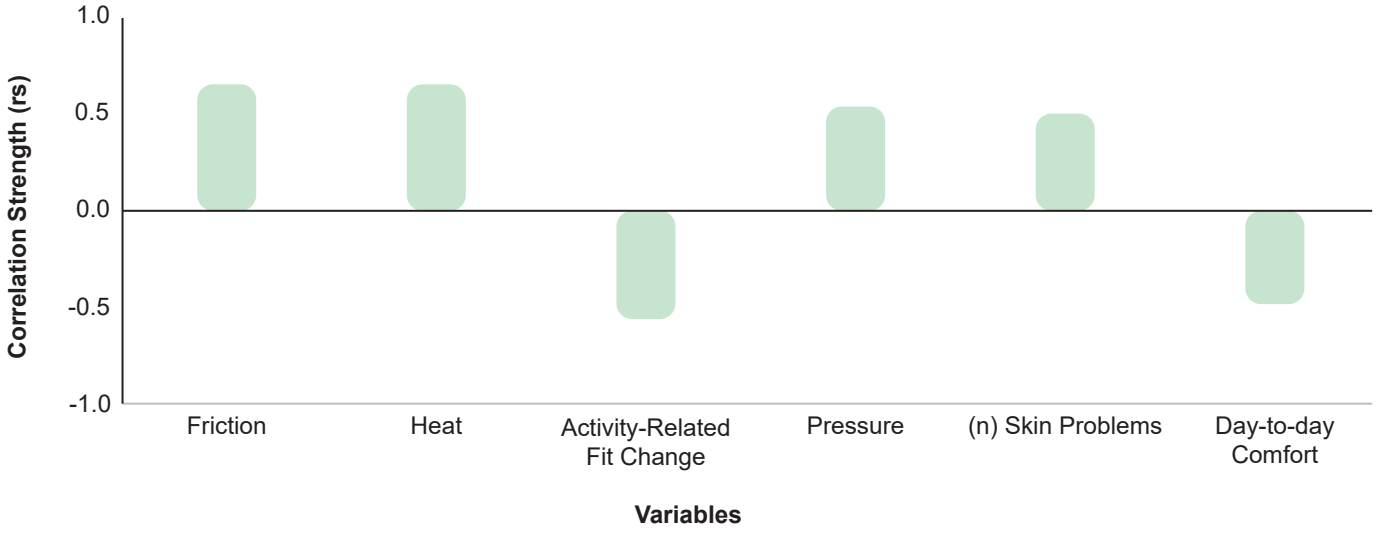


Figure 16 *- Strongest correlations to adjustment frequency*

Socket fit and pressure distribution responses were also clustered and shown to be a secondary factor associated with discomfort. Discomfort caused by pressure, and discomfort caused by friction correlated strongly with one another, rs(20) = .59, p = .004. Interestingly, there was only moderate correlation with the thermal cluster, which could indicate that mechanical and thermal discomfort are driven by separate causes.

Users of prosthetics with a foam liner (M = 3.40, SD = 1.52) averaged more pressure discomfort than silicone liner users (M = 2.25, SD = 0.93), however it is also important to recognise that these liners are typically indicative of a different type of prosthesis suspension method entirely.

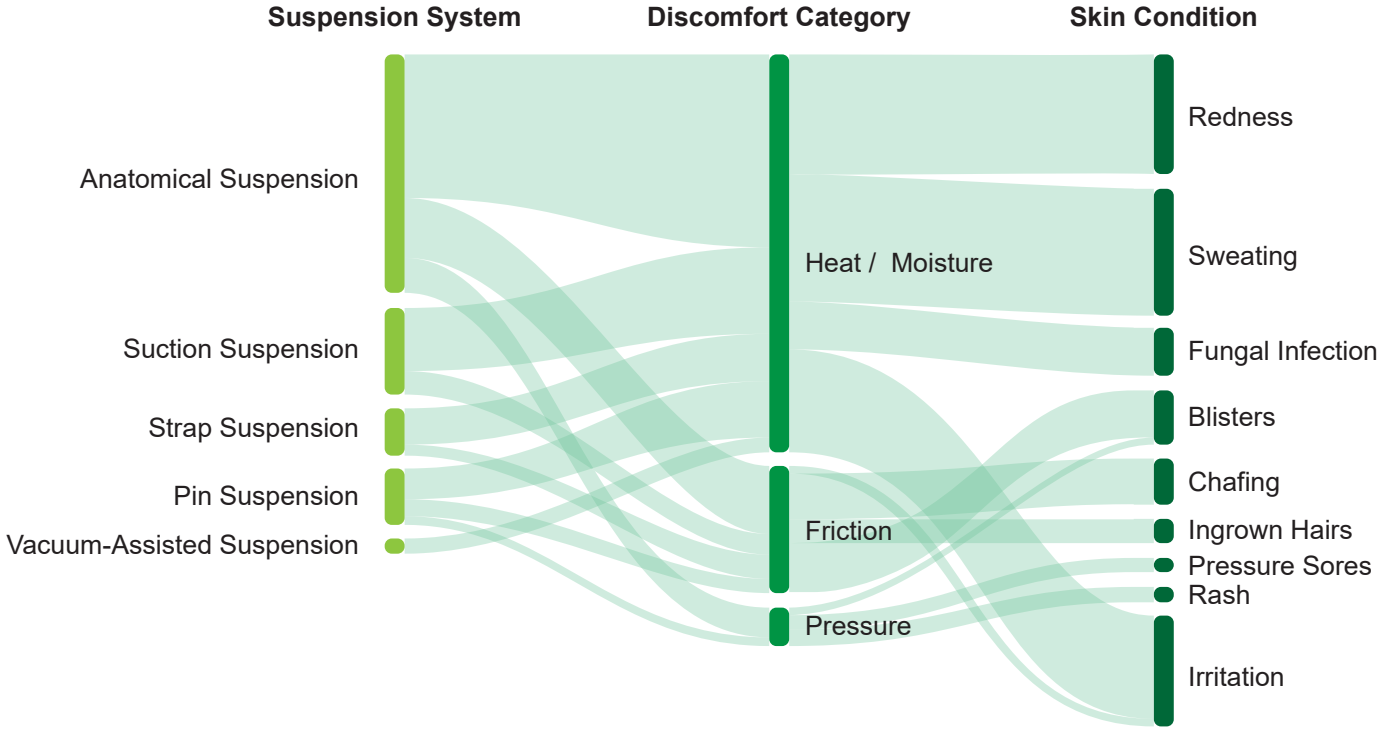


Figure 17 *- Sankey Flow Diagram of Suspension System, Discomfort Category, and Skin Condition*

DISCUSSION

Identifying the gaps in the literature.

6.0 DISCUSSION



Literature identifies thermal regulation and moisture accumulation within the socket as a persistent and under-addressed barrier to comfort for lower limb prosthetic users (Liu et al., 2025; Diment et al., 2019). The data collected in the scope of this investigation directly reinforces this, as heat and moisture were the most frequently reported causes of discomfort across every suspension type in the survey, alongside the interview and observation. The Prosthetist also independently reported that almost every client they see experiences some form of skin condition related to prosthetic use.



Benchmarking of ten existing socket, liner, and suspension products found that solutions consistently trade mechanical adjustability (e.g. the ProsFit 3D Printed Socket, Quorum Quatro) for breathability (e.g. the Martin Bionics Socket-less Socket, WillowWood One System), and no product scores well on both simultaneously. The most common combination, a rigid carbon fibre shell with a foam liner, remains the least breathable of all products reviewed. This aligns with survey findings - that heat retention, rather than mechanical load, is the stronger predictor of skin condition count. Current products may underestimate the importance of designing to reduce heat-entrapment relative to its real-world impact.



Findings from the 22-respondent survey were reinforced by the interview with the participant. How often a user needs to adjust their own socket during the day, correlated with nearly every discomfort measure captured (friction, heat, pressure, skin problems), suggesting it functions as a broad, easily measurable proxy for overall socket dysfunction. The type and frequency of skin condition also differed by liner and suspension system, with foam liners linked to pressure sores and rash, silicone liners to ingrown hairs, and anatomical suspension systems to fungal infection and blisters, indicating that discomfort is not a single undifferentiated symptom but several mechanistically distinct problems.



These findings help to expose the gap. Existing literature and products treat thermal, moisture, and mechanical discomfort as separate problems, but this research shows they are one and the same. Moisture and heat act as upstream causes of both mechanical irritation and skin conditions. This reinforces the need to pursue a design direction that addresses thermal and moisture regulation as the primary lever for improving comfort, rather than treating mechanical fit adjustments as the main solution.

The data collected does have significant shortcomings that are worth noting. The survey's sample size (n=22) is small, and once categorised, the subgroups are even smaller. Recruitment through the Para Dolphins athletes alongside general amputee Facebook and Reddit communities may also have skewed the sample toward more active, digitally engaged, and problem-motivated respondents. This is supported by consultation with the Prosthetist, who indicated suction suspension is the most common system encountered in practice, despite anatomical suspension being heavily represented among the survey respondents, which may suggest bias in who chose to respond (e.g. the respondents were interested in the survey due to wanting to voice their issues). Both the interview and observation may not properly generalise users with different activity levels or socket needs. A planned coded interview with a second certified Prosthetist could not be completed within the project timeline due to them falling ill. The workshop discussion in lieu of this was informal and unstructured, and only reflected experiences within a single workplace. This consultation was not subjected to the same thematic coding process as the interview, so its contribution could only be treated as contextual industry insight rather than systematically analysed data.

DESIGN IMPLICATIONS

Design priorities - what are the problems a next-generation prosthetic socket must address?

7.0 DESIGN IMPLICATIONS

The findings from the research and data breakdown can be translated into a clear set of design priorities. These are ranked by both the strength of evidence behind them and the size of the gap identified in the current market.

1

Heat and moisture management must be the number one design priority.
This was the most consistent, most strongly correlated, and most physically evidenced finding across all four data sources. Benchmarking confirms that most current products largely fail to address it without major sacrifices. Any design that focuses on comfort without addressing thermal regulation is leaving half the problem unsolved. This includes managing, not only internally generated heat and sweat, but external heat load from solar absorption through the outer shell, an opportunity not mentioned by any benchmarked product or identified by reviewed literature.

2

Socket fit must manage pressure and friction.
Anatomical suspension, in particular, was consistently linked to lower comfort, greater number of skin conditions, and the poorest overall performance in the dataset. This indicated that self-suspension via limb shape alone places massive mechanical load on the skin. A design solution should distribute load more evenly than current anatomical or liner-dependent systems, while also accommodating the volume fluctuation reported by users throughout the day.

3

A socket must be durable and waterproof.
Durability featured directly in the interview, including a liner failure (Appendix A) during a major overseas competition, and a subsequent multi-week repair delay. Most products in the benchmarking review with improved breathability achieved so at the cost of durability. Waterproofing is also a related requirement given users' desire to wear their prosthesis during water-based activity, such as wading at the beach.

4

Aesthetics and customisation are a requirement, not an afterthought.
The literature and research both indicate that a prosthesis' appearance is tied to user identity and confidence. Benchmarking showed functionality and aesthetics are typically treated as competing goals, with more functional products often scoring lowest on appearance. A successful design should allow for personalisation or an aesthetically considered finish without compromising performance.

5

A socket should be easily cleanable.
Given the strong role of trapped moisture and skin conditions such as fungal infection, a design that is difficult to clean, or one that does not dry quickly, risks reintroducing the same problems it is meant to solve, regardless of how well it manages heat during wear. When survey respondents were asked what designers and clinicians often overlook, one participant simply answered "easier cleaning" (see Appendix B).

8.0 CONCLUSION

This research report aimed to investigate every factor pertaining to discomfort at the prosthetic-skin interface for lower-limb prosthetic users. Identifying areas for design improvement through literature review, benchmarking, and primary research, it has been established that thermal and moisture management remain a persistent, under-addressed barrier to comfort. Existing products treat breathability durability, and adjustability as separate issues, rather than aiming to resolving them as one.

Primary research triangulated and reinforced these findings. Heat and moisture were confirmed to be the most significant and interconnected causes of discomfort across every data source, and were also closely linked to a wider range of reported skin conditions. Anatomical suspension solutions consistently performed the worst across most categories. These findings point to necessary design priorities of heat and moisture management, fit, durability, waterproofing, ease of cleaning, and aesthetics. These priorities will inform the concept development and design resolution undertaken in the second half of the project.

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