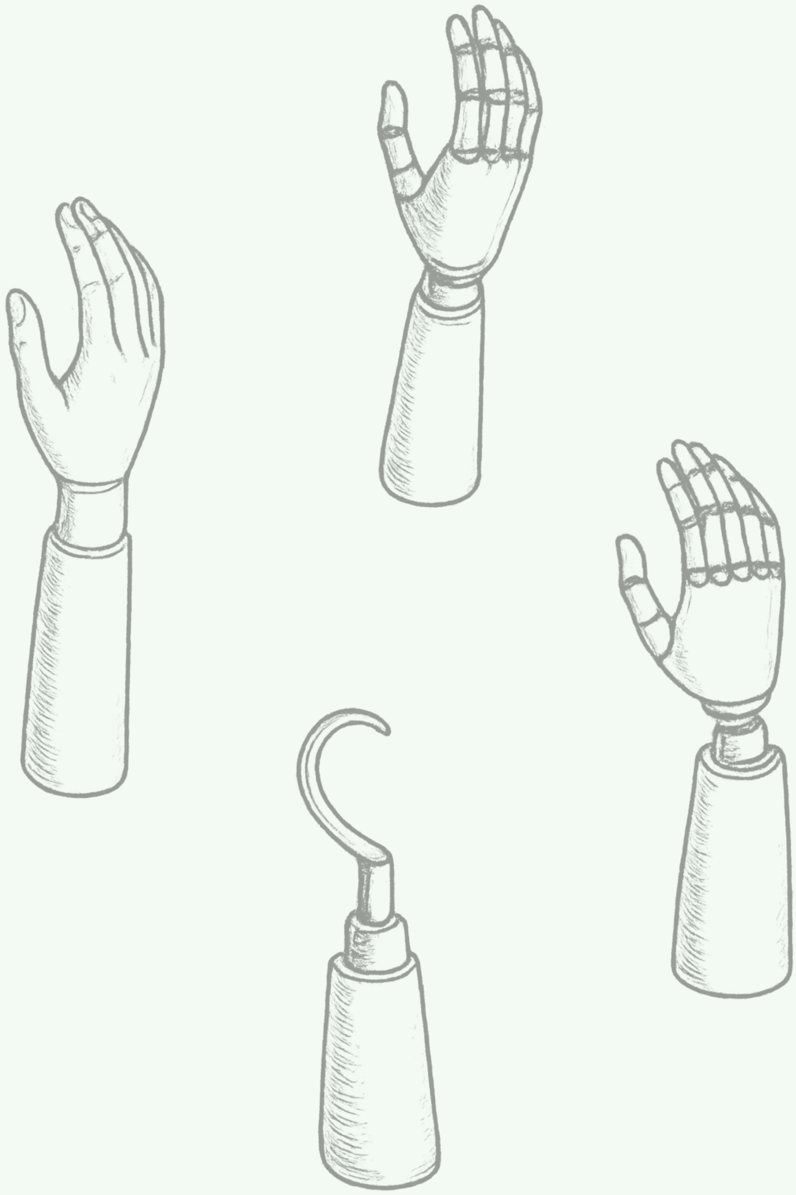
REDUCING PROSTHESIS REJECTION AMONG TRANSRADIAL AMPUTEES

A RESEARCH REPORT TO IDENTIFY OPPORTUNITIES FOR PARAMETRIC GRIP SYSTEMS AND CUSTOMISABLE TOOL HANDLES.

JASPER DETTRICK I N10463003



Jasper Dettrick

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EXECUTIVE SUMMARY

This research report investigates the design, function, and user experience of transradial amputees and related prostheses through literature review, surveys, and archival video analysis. Key findings indicate users prefer hand-like prostheses over hooks or prehensors but face challenges with weight, comfort, and functionality, while experts in the industry (prosthetists) balance design, cost, and usability. Aesthetic, customisation, and personalisation were shown to be just as important to the user as function, although it is highly dependent on user requirements. The literature review, benchmarking, and research showed advances and limitations in myoelectric and body-powered prostheses as well as end-user considerations. Overall, the study emphasises the importance of personalised, functional, and user-centred prosthetic design to improve usability, satisfaction, and quality of life for amputees.

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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 subject or for 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.

Jasper Dettrick

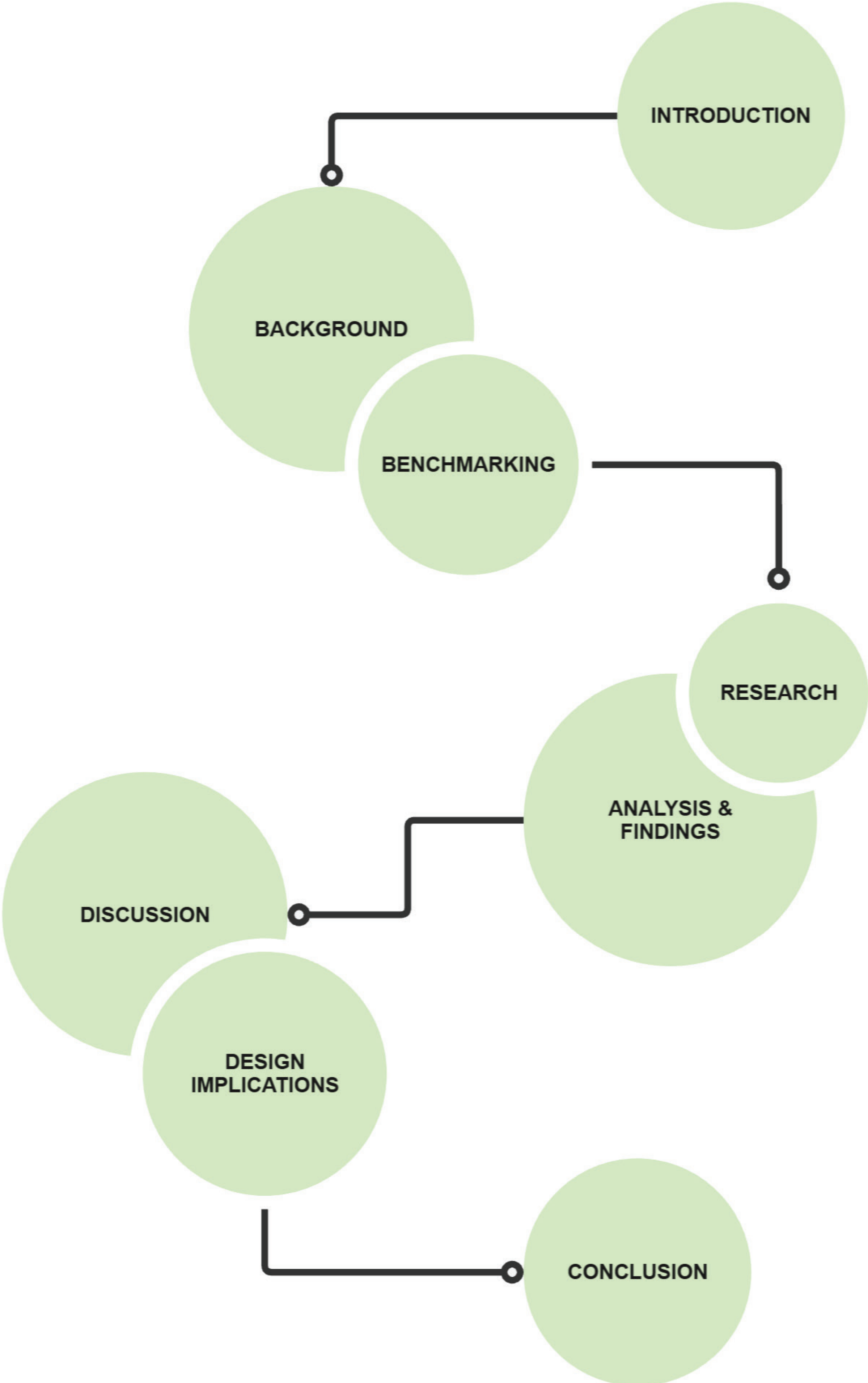
05/09/2025

AI USE STATEMENT

I have utilised Generative AI in this report (Chat GPT) to assist in various ways. The ways I have used AI includes (1) editing sections of text to ensure clarity, conciseness, and cohesion, (2) assistance with finding and organising sources for section 1 - background, (3) helping to categorise some of the themes/subthemes during the thematic analysis in section 2, (4) Identifying some limitations of my research methods (5) Generate background imagery of prostheses and hands.

Jasper Dettrick

05/09/2025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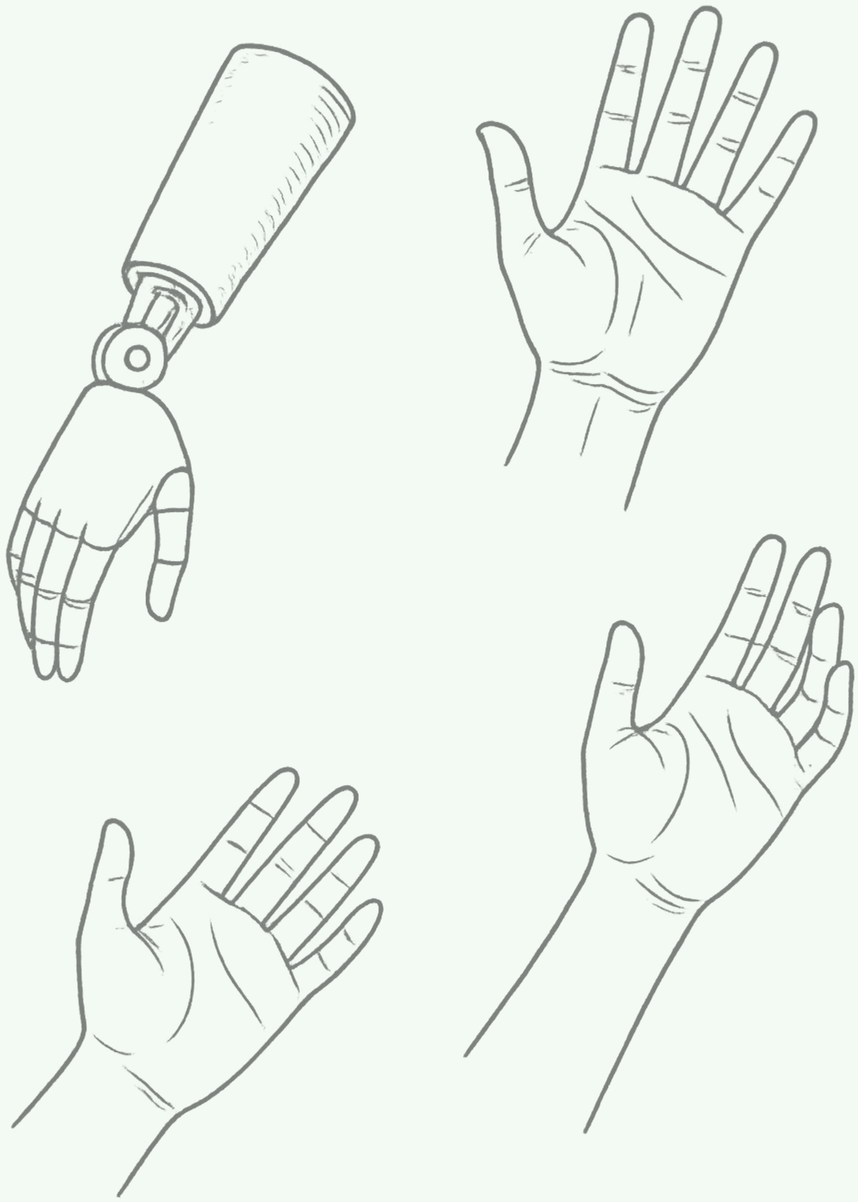

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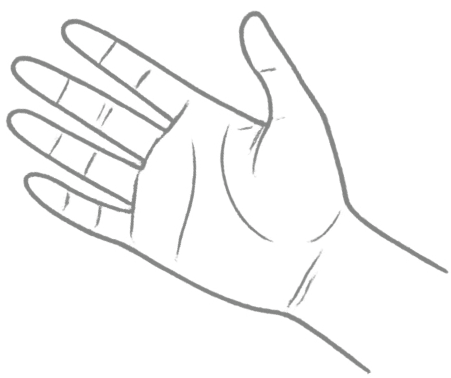
INTRODUCTION, BACKGROUND & BENCHMARKING



INTRODUCTION

Our earliest primate ancestors are thought to have developed partially opposable thumbs as far back as 60 million years ago. Since then, fine motor control has evolved to allow us to (quite literally) feel the world around us, providing the ability to eat, drink, type, write, tinker, and even review this document. To translate Aristotle: “The human hand is the tool of tools.”

For those who are born without hands or who lose them through injury or illness, daily life may present unique challenges - but also opportunities for adaptation and innovation. Modern design, engineering and medicine can do extraordinary things however, prosthetic hand technology has not yet reached the full dexterity, sensation, and versatility of the human hand.

The history of prostheses is distinct in that it is marked both with great progress as well as new challenges. While some aspects of prostheses design have advanced dramatically, emerging technologies have introduced new complexities into how people without hands experience and navigate the world. For transradial (below-elbow) arm amputees, prostheses design plays an important role in daily life. Through thoughtful, user-centred design, there are opportunities to enhance function, comfort and overall quality of life.

This report lays a foundation for innovative prostheses design. It begins with secondary research into prostheses and transradial amputees, then reviews existing products to highlight common strengths and issues. Primary research, through surveys and archival observations (video review), builds on this knowledge. The report concludes with discussion, design implications, and recommendations to guide future prostheses development.

BACKGROUND

Transradial Amputees and Prostheses

Transradial (below the elbow) amputation is the most common upper-limb amputation [1], with modern estimates suggesting around one million individuals worldwide are affected [2]. Despite advances in prosthetic technology, rejection remains high: almost one in three amputees discontinue use, often reporting discomfort, weight, or limited function [3]. Most users (~63%) rely on body-powered hook prostheses, while the remainder use myoelectric systems [4]. Historically, transradial amputees were predominantly blue-collar workers [5], but recent studies show many transradial amputees are now higher educated and have a corresponding job [6]. A 2013 survey found 69% of upper-extremity amputees changed or lost employment post-amputation, those who returned to work were usually in a clerical role[7]. A 2022 study reported an average participant age of 41, with 60.8% employed at survey time, many with university qualifications [8].

System Analysis

According to the *International Confederation of Amputee Associations* and the *VA/DoD Clinical Practice Guideline for the Management of Upper Limb Amputation Rehabilitation*, the current system that an amputee will generally go through is as follows[9, 10]. See Figure 1 below.

System Analysis Map 1

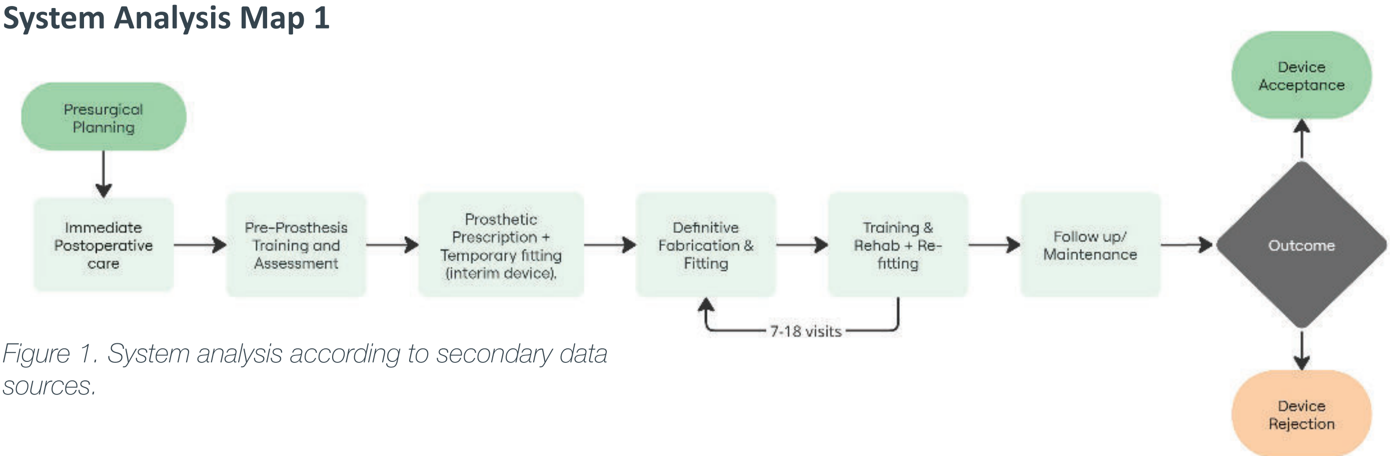


Figure 1. System analysis according to secondary data sources.

...SO WHAT CAUSES REJECTION?

Ergonomics, Weight and Usability of Prostheses

The two dominant prostheses categories each have their limitations and advantages. Myoelectric devices have been the focus for research and development over the last decade despite persistent issues with electrode sweat, calibration drift, electrode displacement, poor robustness, lack of intuitive control, absence of sensory feedback, reliance on a single sensor modality, high cost, heavy weight, limited durability, long training requirements, and high abandonment rates [11]. Body-powered prostheses are superior in most functional regards while also being cheaper [5]. Users, however, don't only care about function—independence and aesthetics are some of the most important prioritised features [12].

Psychosocial Impacts and Support Needs

There are varying findings on the appropriate social settings for amputees and prostheses. One article suggests that in the initial stages of prosthesis adoption, support and acceptance from family and friends is critical to a patient's mental adjustment [13]. Another study reports that amputees hiding their prostheses reduces stigma, supports social interaction, and reduces emotional difficulties commonly associated with limb loss [14].

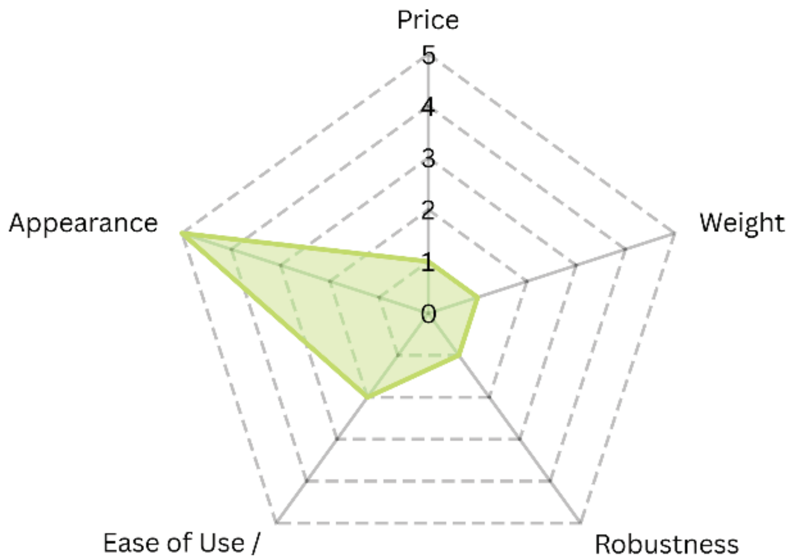
BENCHMARKING

Benchmarking provides a structured comparison of prosthetic devices, highlighting the strengths and weaknesses of different approaches to upper-limb design. Given the wide variety of prosthetic types available, four representative products were selected: one myoelectric device, the iLimb by Touch Bionics (now Össur), and three body-powered devices, the Hosmer Hook 5XA (Hosmer), the TRS Adult Prehensor (Steeper Group), and the Becker Hand (Becker Mechanical Hand Co.).

The benchmarking analysis draws from Schweitzer et al. (2018) [5], which examined user-driven prosthetic design in a highly demanding work environment. These devices were evaluated against common criteria: robustness, ergonomics and ease of use, weight, appearance, materials, and cost on a scale from 1 (bad) to 5 (good).

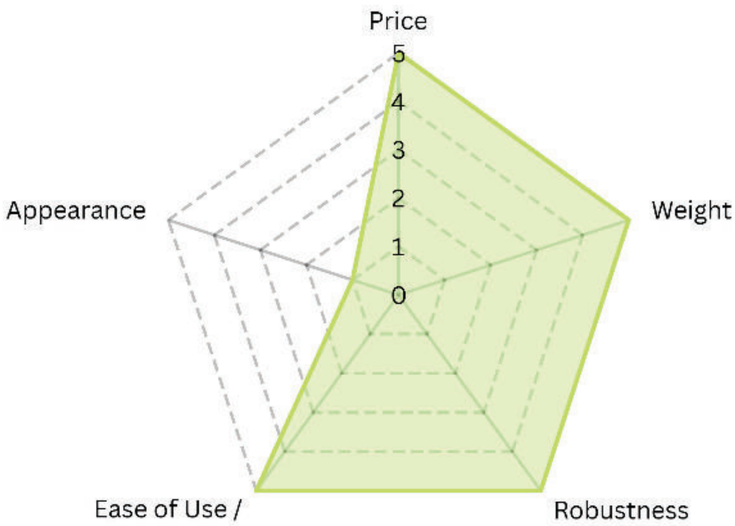
iLimb

The iLimb, produced by Össur, is available in three main models—the Quantum, Access, and Ultra—and is primarily constructed from titanium with a cosmetic rubber glove. While visually futuristic and clean, its robotic appearance often attracts unwanted attention. A major limitation is durability, as the glove tears easily; replacements cost USD $300–700, and third-party options risk voiding the warranty. Ergonomically, users report sweat interfering with electrodes, shoulder pain from weight, skin abrasions, and overall poor reliability. At approximately 630 g and priced around USD $90,000, the device is heavy, costly to maintain, and difficult to justify in practical use.



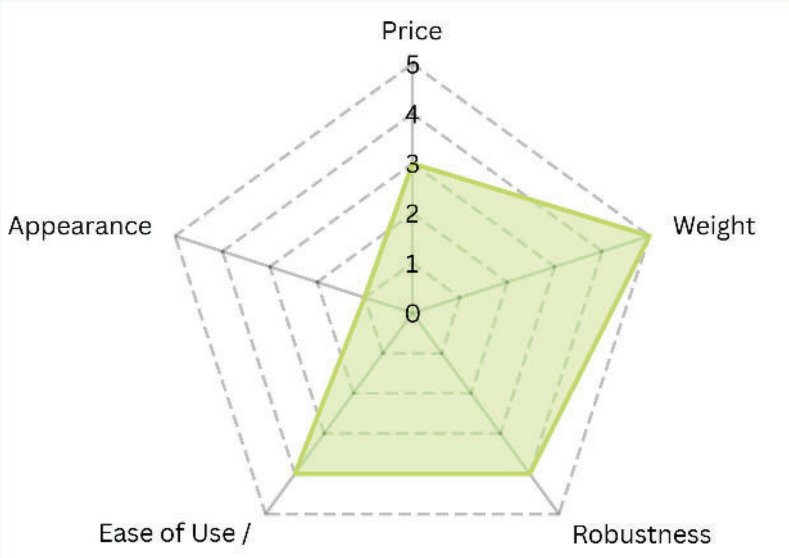

Hosmer Hook 5XA

The Hosmer Hook 5XA is a body-powered prosthesis known for its robustness and durability. Its simple, reliable cable design makes it easy to use, with functionality prioritised over aesthetics. At just 113g, it is extremely lightweight compared with most alternatives. The device is constructed from steel or aluminium alloys with silicone tubing and rubber bands, which are affordable and easy to replace but typically require renewal every one to two weeks under heavy use. While non-cosmetic in appearance, the hook remains highly practical. Priced at around USD $700, it is an accessible and cost-effective prosthetic option.



TRS Adult Prehensor

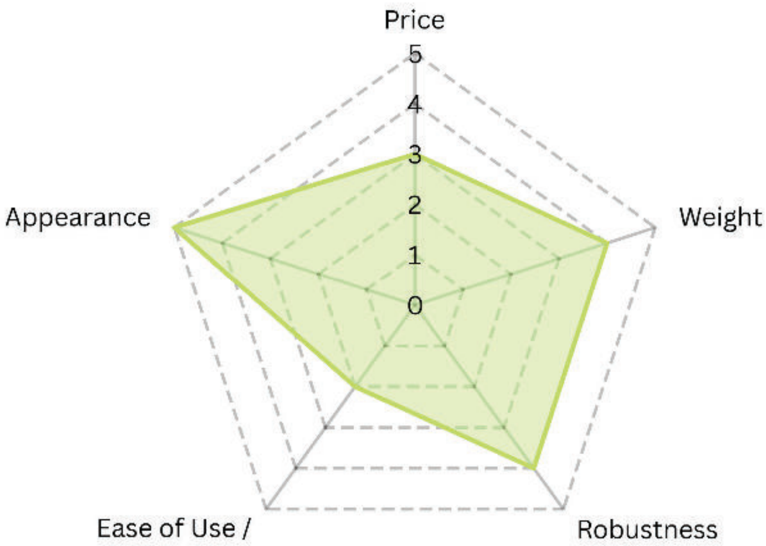
The TRS Adult Prehensor is a robust and durable body-powered device designed for functional reliability. It operates through a simple cable system that is easy to control and provides users with some sensory feedback. Weighing 284g, it is heavier than the Hosmer Hook but remains manageable for daily use. Constructed from steel or aluminium with plastic covers, its claws are enhanced with sheet rubber, double-sided tape, and nitrile glove fingers to improve grip, though these components typically require replacement every one to two weeks under heavy load. Non-cosmetic and mechanical in appearance, the device is priced at around USD $2,000.





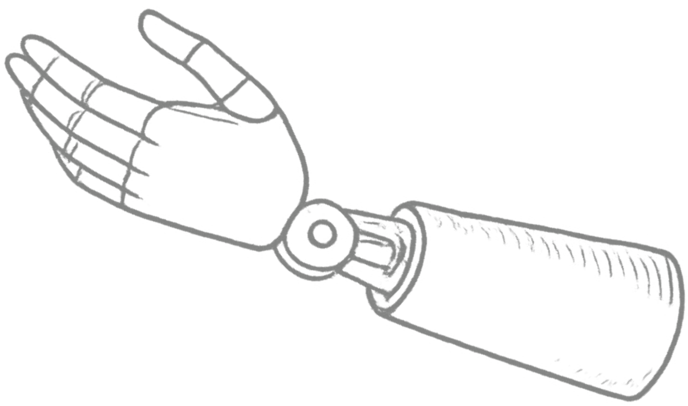
Becker Hand

The Becker Mechanical Hand is a body-powered prosthesis recognised for its robustness and long-standing use. It provides functional reliability through a simple cable system, offering jointed five-finger movement with an automatic locking grip. The device is constructed from durable materials. Models use wood or plastic components, and it can be fitted with standard gloves to improve grip and appearance. It is lightweight and easy to operate. Priced at approximately USD $650, the Becker Hand is an affordable option that balances functional utility with basic anthropomorphic form.



02

RESEARCH, ANALYSIS & FINDINGS



METHODOLOGY

This research adopted a mixed-methods exploratory approach, combining qualitative and quantitative techniques. A triangulation strategy was applied to strengthen validity by drawing from multiple data sources. The aim was to capture both expert perspectives on prosthetic design and industry standards, and end-user experiences of living with prostheses. Expert-driven insights offered both a top-down understanding of professional knowledge and a bottom-up perspective of daily lived experience. This methodological approach enabled the identification of user goals, unmet needs, and emerging opportunities that informed later design implications.

METHODS

Survey

Duration: Approx. 20 minutes
Distribution: 70 invitations emailed, 10 responses received (response rate ~14%)
Participants: 9 prosthetists, 1 manufacturer
Format: 30 questions (15 multiple-choice; 15 open-ended)

A survey was circulated to industry experts, primarily prosthetists, with details included in the appendix. Simple descriptive statistics were used to analyse categorical variables, while conceptual thematic analysis was applied to qualitative data. This mixed approach provided both quantitative and qualitative insights into the prostheses industry in Australia, addressing gaps in the secondary research (see Section 1) and surfacing contemporary challenges and perspectives within the industry. The survey included Likert scale (1–10), yes/no, multiple-choice, and open-ended questions. Likert scales measured influence, difficulty, or importance, yes/no and multiple-choice questions revealed specific patterns, and open-ended questions elicited detailed explanations of practices, preferences, and challenges. This combination allowed respondents to both quantify their opinions and expand on their reasoning where relevant.

Archival Observation

Two publicly available videos were selected to capture detailed, real-world experiences of prosthesis use:
1. "One Hand Bike Check – 2017 Santa Cruz Hightower Adaptive Mountain Biker" (Eric, a transradial amputee).
2. "Reviewing a Bionic Hand!" (Marques Brownlee, technology reviewer).

Both videos were transcribed, time-stamped, and thematically coded to identify recurring ideas. This process revealed practical challenges, user priorities, and emotional responses not evident in the literature or survey data. Coding was structured around system and process (fitting, adaptation, modification), aesthetic factors (appearance, perception, social implications), and functional aspects (capabilities, durability, ease of use). This approach offered an additional user-centred perspective to complement the professional insights gathered from the survey.

ANALYSIS & FINDINGS

In the primary research, quantitative data were analysed using simple descriptive statistics for both univariate and multivariate variables, while qualitative data were interpreted through thematic coding of open-ended responses.

Survey (Qualitative Data):

The qualitative survey data was analysed using conceptual thematic analysis. Each response was manually reviewed and sorted into categories based on recurring ideas. Repeated mentions of similar topics were grouped together under 'Codes' to highlight common challenges, user preferences, and emerging opportunities. Initially, the dataset appeared random and unlinked - *see Figure 2*. The 'mentions' column was usually just '1'.

	The negative effect on the contralateral limb used to create the control motion.	[illegible]
	The usual	1
Concerns	Approval times from funding bodies.	1
	Commonly complain that prosthetic devices are too heavy.	1
	Many clients comment on the difficulties resulting from a lack of proprioception, weight of prosthesis, complexity in use, lack of fine control etc.	1
	No	2
	Not in my experience	1
	Not that come to mind	1
	Process can be time-consuming.	1
	The reality of upper limb prostheses almost never meets expectation. No mechanical device can come close to the versatility, sensitivity and control of the human hand. Confronting this reality and openly discussing individual needs with the end user allows us to design purpose specific tools that can improve quality of life rather than expensive disappointments.	1
	Time between visits.	1

Figure 2, example of manual review and tabulating qualitative responses.

Responses were then sorted into tables organised by sub-themes, each supported by a representative paraphrased version of their quote – as shown in *Figure 2 (above)*. To highlight frequency, similar responses were combined with a 'mentions' column, clearly showing recurring issues - *see Figure 3 (next page)*.

Theme	Sub-Theme	Mentions
Activities	Various activities – creates adaptations with prosthetist	4
	Sports/physical activities	2
	Work/occupation-related activities	1
Body-Powered Drawbacks	Aesthetics issues	1
	Bulky/Clunky	2
	Functional limitation (vs real hand)	1
	Harness discomfort/fatigue	3
Concerns	Device weight complaints	2
	No major concerns reported	4
Extra	No additional comments	3
Future	Improved functionality	1
	Lighter devices	2
	More innovation & tech	1
	Reduced cost	3
Myo Drawbacks	High cost	2
	Heavy/Weight issues	5
	Usability/learning curve	1
Passive Drawbacks	Aesthetics issues	1
	Lack functionality	5
	Outdated technology	1
	Too task-specific	1
	Weight/comfort	1
Process	Clinical process steps (similar processes)	5
	Multidisciplinary team involvement	4

Figure 3, organised responses for digestible data review.

Finally, the data was distilled from the coded frequency table into a pie chart to show the draw-backs of various typs of prostheses (*see Figure 4 below*) and a bubble map to show other general findings (*see figure 5 on the next page*), providing a quantifiable visual overview of qualitative insights that could be more easily discussed and drawn into conclusions. Some responses carried weight into more than one section bubble map as they mentioned more than 1 sub-theme - *see Figure 3 (above)*.

Prostheses Drawbacks

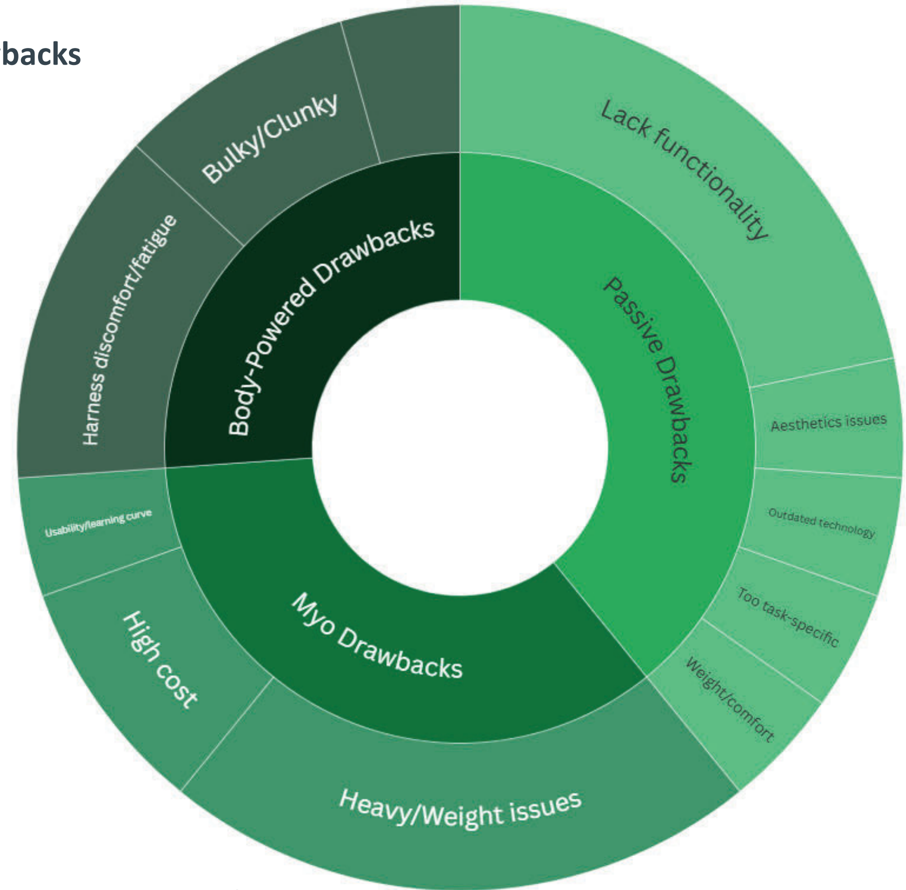


Figure 4, Pie Chart. Prostheses drawback findings

Repeated Themes

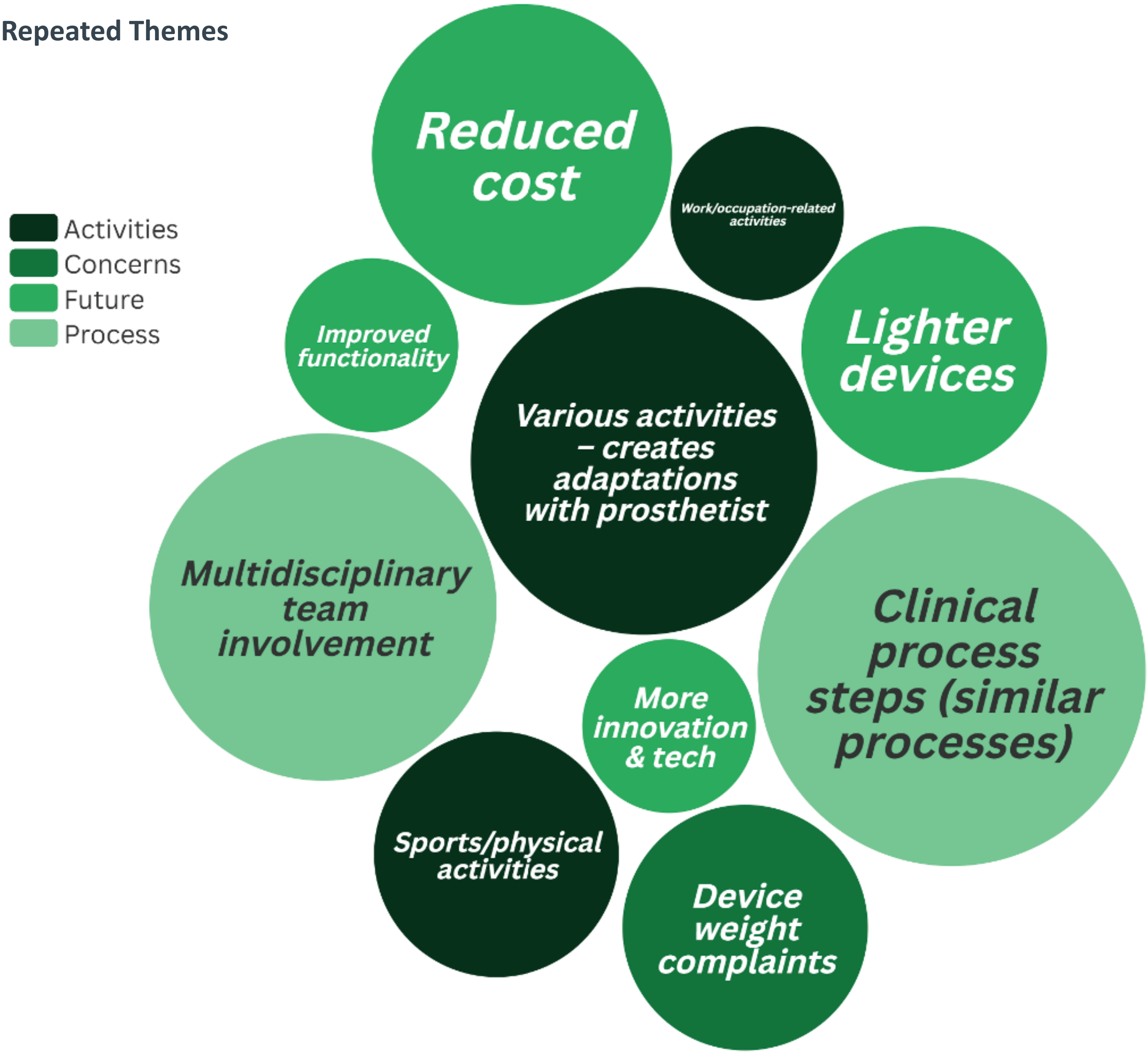
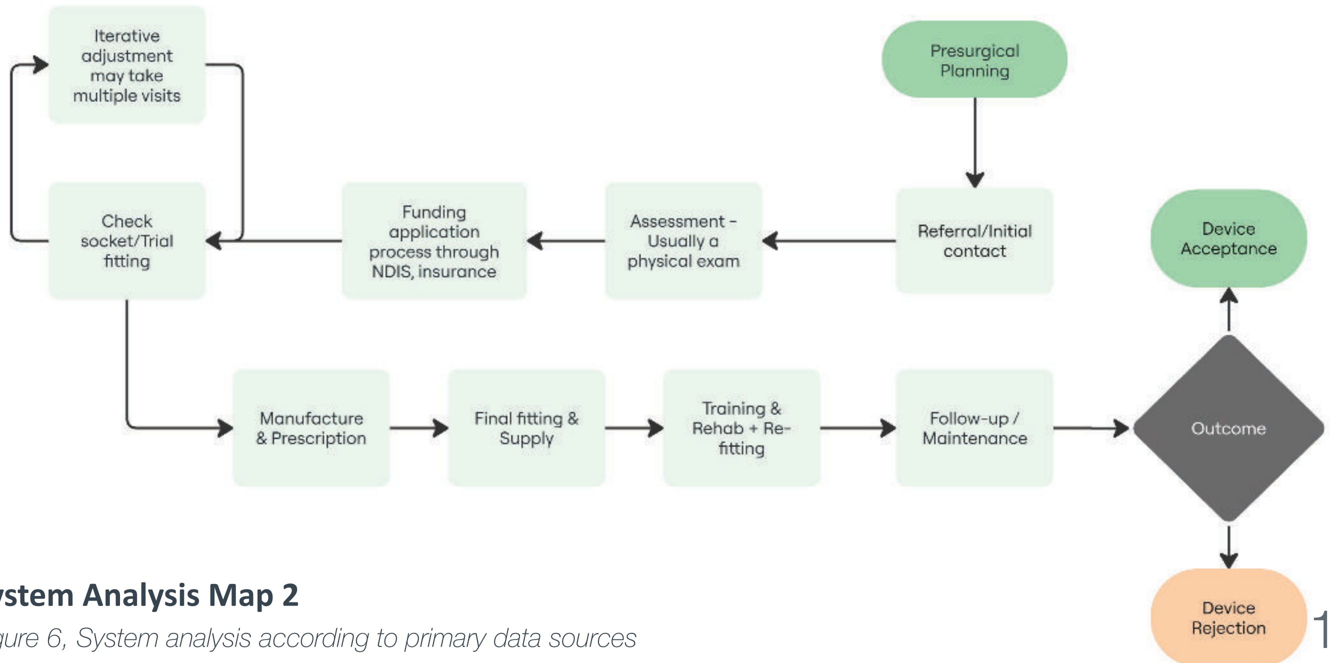


Figure 5, Summary Bubbles of quantitative findings

Survey responses were combined to outline the typical amputee pathway - *see Figure 6*:



System Analysis Map 2

Figure 6, System analysis according to primary data sources

Survey (Quantitative Data):

Univariate and multivariate survey data was analysed using descriptive statistics, with open-ended responses summarised through simple counts.

Some of the research was intended to be quantitative but yielded more open-ended responses in follow-up questions. This was categorised as positive, negative, both, or neither. Experts were questioned if their patients reported anyone noticing their prosthesis with the follow up question -

"In your opinion, does this have an overall positive or negative mental impact on them?"

See responses *in Figure 7 (below),*

Negative
This is a complex question. Negative.
Negative.
Perhaps a feeling of 'otherness'. I feel like this could be said for all amputees.
Negative, in some isolated cases it has been reported as a positive
Depends based on their level of self-esteem.
This depends on expectation, desires and needs and individual personality. Losing a part of your body is very traumatising. Realising that the most exensive technology is a poor replacement can be equally traumatising if handled poorly.
More commonly a negative impact, but some users are very positive about it.
Negative

By applying a combination of descriptive counts and some basic statistical analysis, these responses were summarised into a univariate dataset (*see Figure 8)* and then the statistics were analysedand plotted into a graph - *see Figure 8*.

Response	Count
Positive	4
Negative	8

Figure 8, Social Impacts - Univariate Statistics

As shown in *Figure 8 & 9,* amputees are usually impacted negatively by their prostheses being noticed.

Mental Health Impacts of Noticing Prostheses

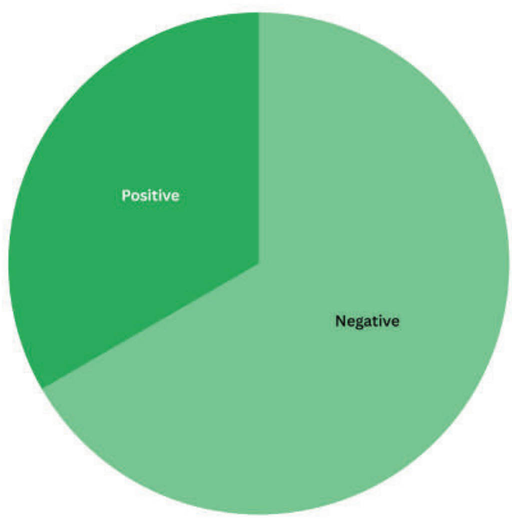


Figure 9, Social Impacts - Univariate Statistics

Another set of questions intended to be quantitative instead produced qualitative responses about preferences for hand-like prostheses versus hooks/prehensors and also preference to a type of prostheses, which were organised using descriptive counts and then statistical analysis. *See Figures 10 & 11 (below).*

Preference	Count
Hand-like	7
Hooks/Prehensors	2
Depends/Contextual	1

Figure 10, Preferences table 1

Preference	Count
Depends/Contextual	4
Myoelectric	3
Body-Powered	3

Figure 11, Preferences table 2

It should be noted that despite preferences towards anthropomorphically typical (hand-like) 3 responses praised hooks for their functional qualities.

Myoelectric and Body-Powered scored similarly and ultimately it is dependent on the users needs or requirements.

This data was made more digestible thorugh the following pie chart, *See Figures 12 & 13 (below).*

Preferences - Hooks vs. Hands

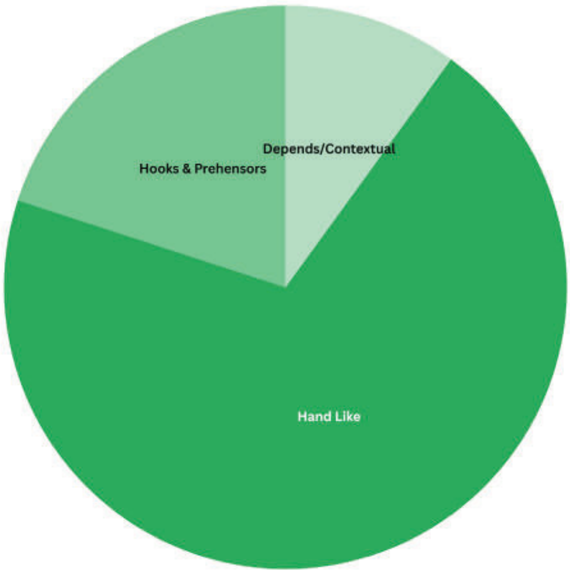


Figure 11, Preferences Chart 1

Preferences - Myoelectric vs. Body-Powered

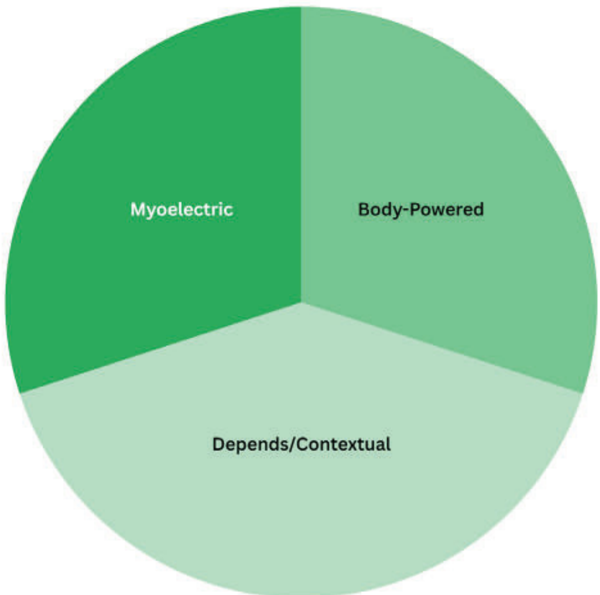


Figure 12, Preferences Chart 2

In your opinion, should patients be given more control over the aesthetic design of their prosthesis?	No	5
	Yes	4
	The only limitation in cost ("ADD OTHER")	1

Figure 13, Section of Quantitative data table (see appendix for full table)

As shown above in Figure 13, multiple-choice questions, many of which included an "add-other" option, produced clear and measurable responses. This data was collated (and sometimes simplified) to identify general patterns, highlight areas of agreement or divergence, and to provide a complementary perspective to the qualitative findings. This was made visually represented in *Figures 14 and 15 below.*

Should Patients be Given More Control Over the Aesthetic Design?

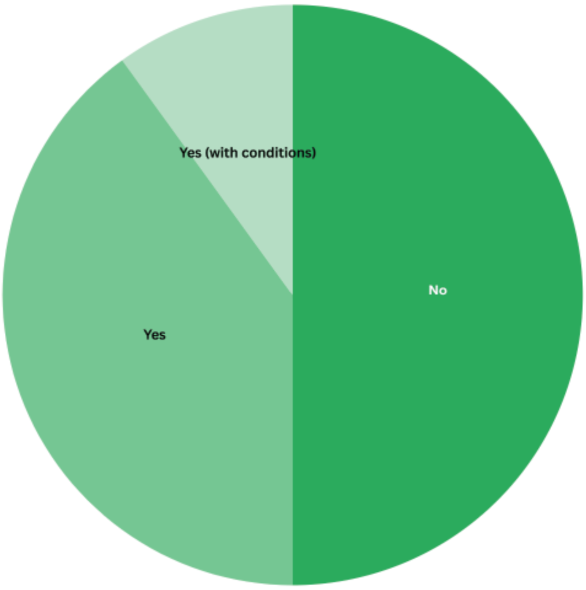


Figure 14, Aesthetic Design Control

Figure 14 shows a clear divide among experts on whether patients should control the aesthetic design, with one comment noting it is the prosthetist's responsibility to guide patients and explain their options.

Should Patients be Given More Control Over the Functional Design?

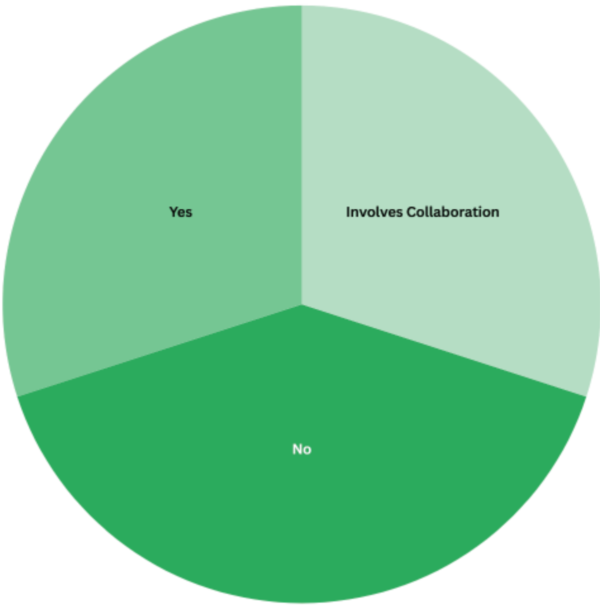


Figure 15, Functional Design Control

Figure 15 shows a similar divide, with more responses highlighting collaboration as key to deciding patient control over functional design.

Likert-scale ratings (1–10) were analysed using descriptive statistics (mean, median, mode, standard deviation, range). Multiple averages were included due to the small sample size, highlighting limitations. For example, in Question 3 (*Figure 16 below*) the wide spread (SD = 3.35) showed varied responses, though three experts rated difficulty as 3/10 (poor).

Question	Count	Mean	Median	Min	Mode	Max	Std Dev
In your opinion, how much influence does the prosthetist have over the functional design (as in control of the capabilities) of the prosthesis? 10 being complete control and 1 being no control.	10	7.2	8	1	8	10	2.740641
In your opinion, how much influence does the patient have over the functional design (as in control of the capabilities) of the prosthesis? 10 being complete control and 1 being no control.	10	5.4	5	1	5	10	2.366432
How challenging is it for the patient to upkeep their prosthetic? 10 being very easy and 1 being so difficult that they cannot do it without help.	10	6.1	7	1	3	10	3.3483
In your opinion, how much influence does the prosthetist have over the aesthetic design (as in visual style, flare, colours etc.) of the prosthesis? 10 being complete control and 1 being no control.	10	6.2	6	2	8	10	2.394438
In your opinion, how much influence does the patient have over the aesthetic design (as in visual style, flare, colours etc.) of the prosthesis? 10 being complete control and 1 being no control.	10	7.1	8	2	8	10	2.424413

Figure 16, Table of averages

Survey Findings

Survey responses indicate that prosthesis users engage in a wide range of work and leisure activities and rely on prosthetists to tailor devices to their individual needs. Many users find prostheses heavy or uncomfortable, with body-powered devices often considered bulky and myoelectric devices too heavy. Patients generally prefer hand-like prostheses, though device choice depends on individual goals. The process involves a multidisciplinary team, and collaboration between patients and prosthetists is critical. Experts are divided on how much control patients should have over functional and aesthetic design, and most agree that prosthesis upkeep can be challenging without assistance. High cost is also a concern, and attention drawn to prostheses can negatively impact users' sense of fitting in.

Archival Video Observations (Qualitative Data):

Archival video observations were analysed to capture user experiences, highlighting challenges, opportunities, and notable aspects of prosthesis design.

Two videos were selected for review (*see Figure 17 to the right*): “One Hand Bike Check – 2017 Santa Cruz Hightower Adaptive Mountain Biker” by Eric, a transradial amputee, and “Reviewing a Bionic Hand!” by Marques Brownlee, a technology reviewer. Each was transcribed and timestamped into short, digestible summaries.

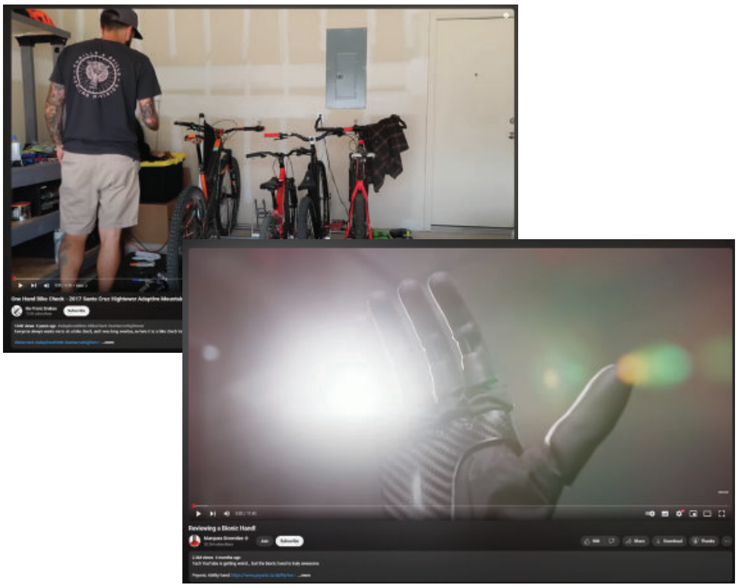


Figure 17, Videos chosen for review

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hole at the end and it clicks on.- now I'm good to go. -inside the carbon is this thick rubber layer and on either side of the carbon are these two windows which helps it breathe a little better if I want to take them off I cinch it with a Velcro which I typically never touch and the arm just stays on no straps trouble my shoulder either. *wait I thought you said this was a bike check.* yeah I did let me start off by saying if you came here to ask a bunch of technical questions about my bike I have no idea what I'm doing

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everyone always says the best bike is the one you have I just happen to have a shitty XC bike my trail bike a dirt jumper and maybe a new toy soon in the upcoming months in the description I'll put links to as many of the things on my bike as I can alright let's check out my cockpit you'll notice that everything is on the left-hand side well duh on the right side is just the knob my prosthetic hooks into - of course I made a modification here after wrecking several times coming off in the

Figure 18, Video analysis - time stamps, transcribed

The footage was coded for themes and sub-themes, supported by direct quotes to clarify the perspectives presented, *as shown in Figure 18 on the previous page*. Relevant quotes, timestamps, and images were tabulated (*Figure 19 below*) under overarching themes and sub-themes, much like the thematic analysis conducted on the survey. Unlike the survey data, these themes were simplified into a short summary of findings that identified practical challenges and user priorities.

Bionic Review	Technology and Innovation	Durability and Accessibility	It's incredibly durable, it's waterproof, and it's cheap enough to be fully covered by Medicare.
		Cutting-edge Features	Carbon fiber, water resistant, fully dextrous, five fingered hands that weigh less than a regular human hand with a rechargeable battery that's controlled by EMG.
	User Experience	Ease of Use	This has to be the fastest pairing Bluetooth device I've literally ever used… connected in like two seconds flat.
		Grip Versatility	This is where you can rotate between a bunch of different preset hand positions, known as grips.
		Practical Functionality	I picked it up and I do actually feel the haptic feedback in the hand.
		EMG Control	Essentially, they'll have a prosthetic, a connection to their arm with EMG, and then the hand will connect to the end of it.
		Haptic Feedback	There's actually a vibration motor where I can feel when I've closed my hand on something.
	Limitations & Challenges	Acknowledged Boundaries	I know I'm not gonna go play ultimate Frisbee or even tie shoelaces or do anything super crazy with this.
	Societal & Emotional Impact	Human Benefit	It's still awesome that even the amount I'm able to do, as a completely untrained user, has me so impressed with the amount of functionality it's able to give back to the people who need it.
		Future Possibilities	They also have these even crazier demos, like connecting it to a brain implant, which… seems to imply that the ceiling is way higher than what we've already seen.
Bike Review	Prosthesis Journey	Riding before prosthesis use	My back was hunched and I was always in pain after rides.
		Collaboration with prosthetist	I met Aaron from Blue Sky Prosthetics… it was a game changer…
		Positive impact of prosthetic	It was a game changer - I was able to ride longer, faster, better.
		Childhood prosthesis limitations	It was essentially a glorified cast with cables.
		Childhood prosthesis aesthetics	It was the stuff of nightmares.
		Modern improvements	This one is so much different - there are no straps and it's made of carbon.
		Modern liners	Made by Ossur… durable silicone with nylon outer cover, used for almost two years.
	Adaptation & Customisation	Modifications for safety & function	I added these zip ties and rubber bands…
		Cockpit adjustments	I stacked my brake levers…

Figure 19, Table of themes from video reviews

The video analysis highlighted several recurring challenges and priorities, which were distilled into key findings reflecting notable or repeated observations across the footage.

Bike Review

Challenges Pre-Prosthesis - Riding caused pain, poor posture, and discomfort.

Prosthetist Collaboration - Partnership in design was pivotal for success.

Positive Outcomes - Improved riding performance (longer, faster, better).

Limitations of Past Devices - Childhood prostheses described as crude and unattractive.

Modern Advances - Lighter carbon construction and improved liners.

Adaptations - Custom DIY modifications (e.g., zip ties, brake adjustments) tailored the device to specific needs.

Bionic Hand

Durability - Device described as tough, waterproof, and affordable.

Features - Lightweight carbon-fibre, EMG-controlled, rechargeable, multi-grip.

User Experience - Easy setup, intuitive control, haptic feedback enhances usability.

Limitations - Still not capable of replicating fine motor tasks or high-demand activities.

Emotional Impact - Restores a sense of function, highly motivating for users.

Future Potential - Interest in brain–prosthesis integration points to further innovation.

Archival Observation Findings

Bionic Hand Review:

The bionic hand is described as durable, waterproof, and relatively affordable, with advanced features including a lightweight carbon-fibre frame, EMG control, rechargeable battery, and multiple grip options. Users report an easy setup, intuitive control, and enhanced usability through haptic feedback. While it improves function and restores a sense of capability and provides strong emotional motivation, it still cannot fully replicate fine motor tasks or high-demand activities. There is also growing interest in future innovations, such as brain-prosthesis integration.

Bike Prosthesis Review:

Prior to using a prosthesis, riding caused pain, poor posture, and discomfort. Collaboration with a prosthetist was critcal in designing a device that improved performance, allowing users to ride longer, faster, and more comfortably. Childhood prostheses were often crude and unattractive, but modern devices benefit from lighter carbon construction, improved liners, and custom adaptations sometimes including DIY modifications such as zip ties or brake adjustments which were tailored to specific scenarios and needs.

LIMITATIONS

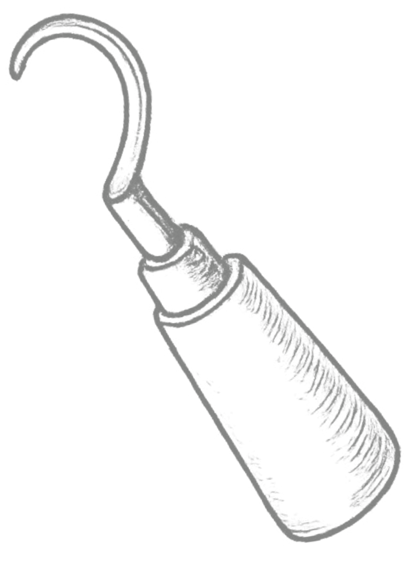
Due to the sensitive nature of prosthesis use and limited time, interviews with amputees could not be conducted, restricting direct end-user perspectives. The survey sample was small, comprising nine prosthetists and one manufacturer, which limits representativeness. While the data provided valuable professional insights, it offered only an indirect view of user experiences. Archival observations added depth but reflected individual cases rather than broader patterns. Benchmarking relied on reported performance rather than hands-on testing, and some literature sources were dated. Some psychosocial findings remained indicative without formal results from psychology journals or articles. Most of the primary results were shaped by Australian healthcare contexts and standards.

SUMMARY

Primary research involved surveys and archival video observations to examine prostheses use and design. Survey responses were analysed using descriptive counts and thematic coding, highlighting functional and aesthetic preferences, device advantages or limitations, and the importance of collaboration with prosthetists. Video analysis identified practical challenges, user priorities, and device advantages or disadvantages. Overall, findings indicate the importance of personalised prostheses, multidisciplinary involvement, and ongoing collaboration to support function and usability.

03

DISCUSSION, DESIGN IMPLICATIONS & CONCLUSION



DISCUSSION

The findings of this study extend and refine the background literature presented in Section 1. Previous research highlighted three major issues: the persistence of high prosthesis rejection rates, the functional trade-offs between body-powered and myoelectric devices, and the psychosocial consequences of prosthesis use. Primary data gathered through surveys and archival observations confirms many of these themes, while also adding new depth to user perspectives.

Both literature and benchmarking emphasised that body-powered prostheses remain functionally reliable, affordable, and lightweight compared with myoelectric devices. This was reinforced in the survey responses, where experts (who were associated with specifically transradial amputees) identified reliability and simplicity as major advantages of hooks, prehensors, and similar body-powered devices. However, the data also clarified the understanding of their drawbacks: users consistently reported that harness systems are bulky and uncomfortable, making long-term wear impractical. This aligns with secondary findings on rejection rates and suggests that comfort—not only functionality—plays a decisive role in long-term prosthesis adoption.

Myoelectric devices, by contrast, continue to demonstrate a mismatch between technical sophistication and user satisfaction. The literature has long reported persistent problems with electrode sweat, calibration drift, fragility, and weight. Benchmarking of the iLimb reinforced these limitations, citing shoulder strain, electrode failures, and expensive consumables such as cosmetic gloves. The survey findings added nuance, showing that patients and clinicians increasingly point to cost and heaviness as the most immediate barriers. This suggests that while advanced devices can offer multi-grip capability and anthropomorphic appearance, their burdens of weight and expense remain primary obstacles to adoption.

Psychosocial impacts were another important area where primary research extended the literature. Section 1 presented varying perspectives: some studies emphasised the value of family and peer acceptance, while another suggested that concealing the prosthesis reduced stigma and improved social interactions. The survey findings supported the latter view, with experts reporting that attention drawn to a prosthesis—whether by friends, family, or strangers—was often experienced as negative by patients. One response described this as creating a “feeling of otherness,” a phrase that captures the underlying psychosocial burden. Taken together, these findings suggest that prosthesis rejection is not only about function but also about the device’s role in shaping identity and social belonging.

The system analysis presented in Section 1, drawn from clinical guidelines, was also supported by survey responses. Participants described similar rehabilitation pathways, confirming that the general process of acute care, fitting, training, and follow-up is well-established. This agreement across research types strengthens the validity of the background system model and provides a stable framework for design considerations (*review Figures 1 & 6*).

In summary, the discussion reveals that while the literature provides a strong technical and clinical foundation, primary research highlights the lived experience of end-users as a decisive factor in prosthesis adoption. Discomfort, bulk, cost, and social visibility emerged as persistent rejection drivers that remain insufficiently addressed by current designs.

DESIGN IMPLICATIONS

The convergence of secondary and primary research provides a clear set of insights for prosthetic design. These can be translated into design principles and opportunities that may guide future development.

Appearance and Identity

One of the clearest findings is the importance of anthropomorphic appearance. Both the literature and surveys show that many amputees prefer devices that resemble the human hand. Benchmarking confirmed that highly “robotic” designs, such as the iLimb, can be eye-catching but often attract unwanted attention. Conversely, body-powered hooks and prehensors, while functional, are rejected partly because of their non-cosmetic appearance. This indicates that prosthetic design should prioritise anthropomorphic forms that minimise stigma while also offering opportunities for personalisation. Customisation options, whether through cosmetic coverings, colour, or modular attachments, may strengthen the connection between device and identity.

Ergonomics and Comfort

Comfort emerged as a critical determinant of long-term use. Harness discomfort, prosthesis bulk, and skin irritation were widely reported in surveys and confirmed in archival observations. Benchmarking also revealed weight as a consistent drawback, particularly for myoelectric devices. A key design implication is therefore the need to reduce harness complexity and overall device weight. Advances in lightweight composites, improved liner systems, and distributed load-bearing mechanisms could directly improve wearability. Designs should also prioritise long-duration comfort, ensuring that users can wear their prosthesis throughout a full workday without pain or skin breakdown.

Functionality and Usability

While body-powered devices remain superior in many functional respects, they lag behind in appearance and fine motor control. Myoelectric devices offer more naturalistic grips but struggle with robustness and intuitiveness. This duality points to hybrid solutions as a promising direction. For example, modular systems could combine the reliability of cable-driven hooks with selective myoelectric enhancements for tasks requiring precision. Archival observations also showed the creative role of user-led adaptations, such as zip ties and custom brake adjustments on bike prostheses. Future designs could formalise this adaptability by incorporating interchangeable components or tool interfaces, giving users the ability to tailor functionality to specific tasks.

Affordability and Maintenance

Cost is a persistent barrier, particularly for advanced myoelectric devices. Benchmarking placed the iLimb at around USD 90,000, with ongoing costs for consumables and repairs. By comparison, hooks and prehensors cost a fraction of this amount and require simpler maintenance. Survey results confirmed that prosthetists are concerned about affordability and the difficulty patients face in maintaining complex devices. Design priorities should therefore include durability, modularity for easy repairs, and simplified upkeep procedures that empower users rather than requiring constant clinical intervention.

Opportunities for Innovation

From the identified themes, several actionable opportunities emerge:

Modularity: Devices designed with interchangeable components, allowing users to adapt for different occupational or recreational tasks. For example, blue-collar workers may benefit from power tool attachments, while office workers may require multi-grip hands for clerical tasks.

Hybrid systems: Combining body-powered reliability with selective myoelectric enhancements to balance functionality with robustness.

Lightweight design: Prioritising reduced bulk and comfort in both harness and prosthesis, ensuring usability throughout long durations.

User-centred aesthetics: Offering anthropomorphic designs with personalisation options to reduce stigma and improve confidence.

Facilitated DIY modification: Building on evidence that users already adapt their devices, designers could create safe, modular systems that encourage customisation without voiding warranties.

Together, these implications suggest that prosthesis design should move beyond a binary body-powered versus myoelectric framework. Instead, future development must focus on integrated, user-centred solutions that address the psychosocial, ergonomic, and functional realities of daily life.

CONCLUSION

The purpose of this report was to identify the requirements of transradial amputees from an end-user perspective and to translate these into actionable design implications. To achieve this, the study combined secondary research, benchmarking of existing prosthetic devices, surveys, and archival observations. Section 1 outlined the prevalence of transradial amputation, the current prosthesis landscape, and the psychosocial challenges associated with prosthesis use. Section 2 presented primary data that extended these findings, revealing user frustrations with weight, bulk, cost, and social visibility.

The study contributes to prosthetic design research by emphasising that end-user experiences and psychosocial needs must be treated as design priorities, not secondary considerations. While technical innovation has advanced features such as multi-grip control, persistent problems with comfort, affordability, and stigma continue to drive high rejection rates. Addressing these challenges requires designs that are lightweight, modular, affordable, and anthropomorphic, with clear opportunities for user-driven customisation.

Looking forward, these findings provide a foundation for prototyping and further research. In particular, modular attachments tailored to occupational needs, hybrid systems that combine body-powered and myoelectric elements, and designs that actively support user identity represent promising avenues. Implementing these opportunities may not only reduce rejection rates but also empower amputees to engage more fully in both work and social life.

04

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05

APPENDIX

Qualitative Data Table

Code	Quote	Mentions
Activities	I have a pitch and putt golfer with a negative handicap. He is missing most of his hand with only the thumb remaining. He has modified his prosthesis to work for his golf. He has a standard hook.	1
	Most do, with the suited terminal devices	1
	Not our focus	1
	Occasionally. Typically participating in these activities has more to do with funding than with capacity.	1
	There are a vast number of custom devices, adaptations and compromises that amputees make to achieve what they want to.	1
	This is a huge question and could write a book on it for each individual case. Short answer is yes and depending on their level of motivation, they will overcome their challenges with effort and or lowering their expectations of their prosthesis.	1
	Too many to list	1
	We work to design custom solutions to achieve a goal	1
	Yes. Working together with prosthetist to make a prosthesis that meets their needs, usually including a terminal device that is specific to their chosen activity i.e., sport specific, etc.	1
	Yes. Yes. Adaptive devices, compensation, revising prosthetic design	1
Body-Powered Drawbacks	Appearance, movement restriction, damage to clothes, grip strength, lack of sensation.	1
	Clunky	1
	Clunky, extensive training required to be effective and useful.	1
	Early fatigue	1
	Heavy, bulky harness/cabling, uncomfortable harness.	1
	None	1
	Nothing replaces a hand	1
	Over-use injury to contralateral shoulder from harness use; limited grip patterns; aesthetics	1
	The negative effect on the contralateral limb used to create the control motion.	1
	The usual	1
Concerns	Approval times from funding bodies.	1
	Commonly complain that prosthetic devices are too heavy.	1
	Many clients comment on the difficulties resulting from a lack of proprioception, weight of prosthesis, complexity in use, lack of fine control etc.	1
	No	2
	Not in my experience	1
	Not that come to mind	1
	Process can be time-consuming.	1
	The reality of upper limb prostheses almost never meets expectation. No mechanical device can come close to the versatility, sensitivity and control of the human hand. Confronting this reality and openly discussing individual needs with the end user allows us to design purpose specific tools that can improve quality of life rather than expensive disappointments.	1
	Time between visits.	1
Extra	"prosthetic" as word is an adjective. You are using it incorrectly. If you use the word prosthetic, there must be a word to follow it, eg limb. If you use it as a noun, it is a prosthesis.	1
	No	1
	The wording of these questions, and the nomenclature used in this survey is poor. The correct term for an artificial limb is a prosthesis, prostheses etc. Additionally I felt many of the questions lacked insight, or steered the responder in only being able to answer a certain way. There are no definite 'yes' or 'no' answers in this industry. Additionally, by it's very nature 'influence' of client or prosthetist is more determined by the clients needs than volition by either party. Clients often have very little idea how their prosthesis is made, or what is required most of the time. In the exception cases the process of prosthesis creation is far more collaborative, but in my experience this is fairly rare. This survey was of disappointing quality, and shows a lack of research and insight into the industry. Hopefully this feedback will assist you in improving the quality and perspective of your project.	1
Future	Better funding	1
	Functional parts	1
	Funding; more myo control systems; good OTs	1
	Innovation and investment, to bring down the price of pattern recognition myoelectrics. More investigation into soft style prostheses.	1
	Lighter and cheaper myoelectric prosthetic devices that are good quality.	1

	Lighter myoelectric options	1
	Partial hand solutions and a lowering in cost to allow technologies to be more available to uninsured clients.	1
Myo Drawbacks	Charging them; issues with myo control; weight	1
	Cost	1
	Each hand still has functional limitations, despite the emergence of new tecnology.	1
	From patients; weight and battery life.	1
	Heavy.	1
	Price, weight, grip strength/speed, lack of sensitivity, water resistance, appearance, battery life, lack of versatility, having to make compensatory movements.	1
	Slow, difficult to learn	1
	The usual	1
	Unreliable, slow, temperamental, expensive.	1
	Weight	1
Passive Drawbacks	Aesthetics; function	1
	Antiquated. Is there anything better?	1
	No active grasp capabilities.	1
	Not functional enough	1
	Not overly functional	1
	That it is passive	1
	That's they are passive	1
	Too task specific to be of general use, most of the time.	1
	Weight and lack of functionality.	1
	lack of movement, weight/heat (although much lighter than other options)	1
Process	1 Initial contact - assessment, education, evaluation of options/prescription 2 Quotation/funding application 3 Casting/Scanning 4 Trial fitting/training 5 Fit/function optimisation 6 Ongoing training - may be completed by specialist Occupational therapist	1
	1. Initial Assessment - ideally with an OT as well - to determine suitability for TR prosthesis and what type of prosthesis might be suitable. Depending on outcomes of assessment, further training with an OT or referral to the upper-limb clinic with a rehab specialist might be required. 2. Once suitability determined, funding report is submitted to funding body i.e. NDIS, Insurance company. 3. Once approval received, patient would be booked for casting appointment to capture the shape of the residuum 4. Check socket fitting to optimise fit of prosthetic socket. Would also determine myoelectric sites at this stage if approved for a myo prosthesis. 5. Definitive fitting of prosthesis 6. Ongoing training with OT 7. Ongoing reviews of prosthesis.	1
	Assessment, Prescription, Funding Request, Manufacture, Fit & Supply, Educate, Review & Adjust	1
	I conduct initial assessments, formulate the prescription of components, take the casts of the clients residual limbs, manufacture the prosthesis itself (and any harnessing), tune the prosthesis, and fit the prosthetic sockets. I also maintain the fit and function of the prosthesis going forward.	1
	Initial assessment and consultation. Joint decision-making on goals and treatment plan. Funding request. Cast. Manufacture. Fitting, follow-up appointments and outcome measuring.	1
	MDT Amputee Clinic with Rehabilitation Consultant, Prosthetist and Physiotherapist. All stages involve P&O.	1
	Post amputation the amputee typically attends an "interim" prosthetic service through their local public hospital service, where the attending prosthetist will assist in review and assist in residual volume managing, once healed and volume has matured the amputee's attending prosthetist would measure and cast him/her for their first prosthetic device	1
	Pt seen at MDT clinic with medicine, PT and OT. Limb prescribed. Cast of residuum. Check socket fitting to prove socket design. Fitting of limb and tuning of harness - supply. Training with OT. Follow up review	1
	Step 1. Patient attends hospital Upper Limb Clinic with rehabilitation team including rehab doctor, OT and prosthetist. Or Step 1. Patient attends prosthetic clinic directly without referral from hospital clinic. Step 2. Assessment is undertaken on how to best cater to their needs. Step 3. Request is sent to funding body for approval of prescribed prosthesis (NDIS, insurance, state funding scheme i.e., EnableNSW). Step 4. Upon funding approval, patient attends our clinic for casting and fitting of prosthesis. This process occurs over several appointments which can take several weeks to months. Step 5. Patient engages with an Occupational Therapist (OT) for training with upper limb prosthetic device. Step 6. Patient attends our clinic as needed for prosthetic adjustments.	1
	They may bring in their own hardware	1

Organised responses

Theme	Sub-Theme	Mentions
Activities	Various activities – creates adaptations with prosthetist	4
	Sports/physical activities	2
	Work/occupation-related activities	1
Body-Powered Drawbacks	Aesthetics issues	1
	Bulky/Clunky	2
	Functional limitation (vs real hand)	1
	Harness discomfort/fatigue	3
Concerns	Device weight complaints	2
	No major concerns reported	4
Extra	No additional comments	3
Future	Improved functionality	1
	Lighter devices	2
	More innovation & tech	1
	Reduced cost	3
Myo Drawbacks	High cost	2
	Heavy/Weight issues	5
	Usability/learning curve	1
Passive Drawbacks	Aesthetics issues	1
	Lack functionality	5
	Outdated technology	1
	Too task-specific	1
	Weight/comfort	1
Process	Clinical process steps (similar processes)	5
	Multidisciplinary team involvement	4

Quantitative data table

Question	Response	Count
In your opinion, should patients be given more control over the functional design of their prosthesis?	No	4
	Yes	2
	Involves collaboration between the patient and healthcare professional ("ADD OTHER")	4
In your opinion, do patients generally prefer myoelectric, passive or body-powered prosthesis?	Myoelectric	3
	Body-Powered	3
	Depends on goals or costs ("ADD OTHER")	4
Do patients report the use of disposable products with their prosthetic like tubular gauze, foams, rubbers or tapes?	No	7
	Yes	3
Both in an empathic and professional manner, do you often find yourself involved with the emotional wellbeing of the patients?	Yes - Often	5
	Yes - Sometimes	4
	No - They don't come to me	1
In your opinion, should patients be given more control over the aesthetic design of their prosthesis?	No	5
	Yes	4
	The only limitation in cost ("ADD OTHER")	1
Do patients/users prefer anthropomorphically accurate (“hand-like”) prosthesis or other forms like hooks or prehensors?	Anthropomorphically Accurate / Hand-like	4
	Hooks / Prehensors	2
	Prefer the look of anthropomorphically accurate (hand-like) designs but the functionality of hooks/prehensors ("ADD OTHER")	2
	Depends on the user's goals ("ADD OTHER")	2