

**Keywords:** protection of vulnerable road users; pedestrians with locomotion problems; road safety; road accidents; protection equipment; mobility; accessibility; demographic forecasts

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## ENHANCING MOBILITY: DEVELOPING A PEDESTRIAN SOLUTION FOR LOCOMOTION CHALLENGES AND ROAD SAFETY

**Summary.** Orthopedic crutch attachments (caps) are an important but underestimated element supporting the safety of pedestrians, including elderly road users with disabilities. A review of the literature shows that this topic is rarely the subject of research and new solutions. In 2022, the multidisciplinary team of the Motor Transport Institute started multi-stage work to develop and implement innovative multi-functional attachments to orthopedic equipment as an element improving the comfort of movement of this group in various weather conditions. Focus group interviews with potential users, which were a part of the project, indicated the most important features of the selection of such a solution, such as material, anti-slip properties, ease of replacement, durability (low abrasion), ensuring stability, and quiet operation. On this basis, the final prototype of the orthopedic crutch attachment presented in the article was developed. In addition, areas related to road safety and pedestrian safety devices were identified, the implementation and promotion of which could improve the functioning of orthopedic equipment users.

### 1. INTRODUCTION

The pace of population aging is now much faster than in the past. Demographic forecasts leave no illusions, and the number of older adults and pedestrians with permanent or temporary locomotion problems (PWLP) will increase [1]. This is especially true in European countries, including Poland. Today in Poland, people aged 65+ already constitute 24.5% of the population. It is estimated that in 2050, people of this age will constitute as much as 37.9% of the total population [2, 3].

According to WHO analyses, all countries face major challenges in ensuring that their health and social care systems are ready to meet these challenges. These changes will undoubtedly force modifications in the functioning of transport systems or their elements in terms of their use by this group of people. Among the facts reported by the WHO, some of the most noteworthy are as follows:

- Each year, about 1.3 million people die in road accidents.
- More than half of all road fatalities involve vulnerable road users (i.e., pedestrians, cyclists, and motorecyclists).
- Road accidents cost most countries 3% of their gross domestic product [4, 5].

With the above facts in mind, the UN General Assembly adopted a resolution for improving global road safety by proclaiming the Decade of Action for Road Safety 2021-2030, with the ambitious goal of preventing at least 50% of road fatalities and injuries by 2030 [6]. The WHO and UN regional commissions, in cooperation with other partners in the framework of UN cooperation for road safety, developed the Global Plan for the Decade of Action [7]. The plan is in line with the Stockholm Declaration; it stresses the importance of a holistic approach to road safety and calls for continuous improvements in road and vehicle design while improving and enforcing the law and ensuring life-

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saving emergency assistance. In addition, it is part of the policy of promoting healthier and more environmentally friendly means of transport (i.e., walking, cycling, and using public transport) [8]. The years 2021-2030 have also been announced as the UN Decade of Healthy Aging, which refers to many different documents, including the Resolution of the European Parliament on the aging of the Old Continent [9]. It also supports the implementation of the UN 2030 Agenda on Sustainable Development and the Sustainable Development Objectives [10]. The WHO is responsible for implementing both initiatives.

The Polish principles of the National Road Safety Program 2021-2030 include designing solutions (e.g., introducing speed limits) that are friendly to all road users, with particular emphasis on the biomechanical limitations of the human body. The argument for adopting this criterion is based on the changing social structure, including the aging population, as well as changes in mobility, which result in an increasing number of vulnerable road users [11]. This makes it necessary to intensify protective measures against pedestrians, cyclists and motorcyclists. Multi-faceted systemic and ad hoc activities are already being carried out in order to support this large and diverse group in terms of mobility and accessibility needs. Such activities may even use simple and improved solutions.

The work of the Motor Transport Institute (MTI) team includes the following stages: theoretical (analysis of the available documents and solutions), conceptual (preliminary solution design, final solution design), research (empirical research, evaluations of the solution prototype, focus group interviews [FGIs], tests of the developed solution by users) and implementation (production for laboratory testing, testing by users, post-test for serial production). This approach allows the elimination of errors and the development of a product that meets high standards.

Therefore, a team of authors designed a prototype of an attachment for orthopedic equipment based on the results of the literature review and an evaluation of similar devices referring to the principles of industrial design and utility design while also taking into account planning standards considering the specificity of PWLP and professional experience, as well as personal experience.

This article includes two stages: the results of the evaluation of the prototype of the cap during the FGI and the final design of this solution. On this basis, three gaps were indicated, the filling of which would improve the functioning of orthopedic equipment users.

## **2. OLDER PEDESTRIANS AS PARTICIPANTS IN ROAD ACCIDENTS IN POLAND**

The analysis of data on road accidents from the Polish Road Safety Observatory, conducted for the purposes of this article, showed that people with disabilities in Poland are very rarely victims of road accidents, and accidents involving them accounted for only 0.02% of all accidents per year in 2022, when there were eight accidents. In 2021, there were 12 accidents (0.03% of the total), and in 2020, there were 10 accidents (0.03% of the total) [12]. The group of seniors (including PWLP) who are victims of road accidents is large.

The list of accidents and victims of road accidents among older adults aged 65+ as pedestrians, drivers, and passengers in the last three years is presented in Tab. 1. In 2022, fatalities in the 65+ group accounted for 21% of all road accident fatalities in Poland. This means that every fifth person who died as a result of a road accident was a senior. Most often, when it comes to pedestrians, this happened as a result of hitting a pedestrian [12]. The number of injured people is noteworthy. For people of this age, any event resulting in an injury or injury can lead to permanent health problems.

## **3. OVERVIEW OF CRUTCH ATTACHMENTS**

The purpose of providing orthopedic equipment is to maintain the human ability to function independently, replace the lost function of the body and strengthen the work of individual organs by performing all activities related to the selection, construction, adjustment, and use of appropriate items. Orthopedic appliances refer to various structural devices designed to stabilize, protect and correct orthopedic disorders [9, 13-15].

Table 1

Accidents and casualties among pedestrians, drivers, and passengers aged 65+ in road traffic from 2020-2022

Year	Accidents		Fatalities		Injured		Including seriously injured	
	number	% of total	number	% of total	number	% of total	number	% of total
2020	4000	16.99%	545	21.88%	3655	13.81%	1429	16,23%
2021	3907	17.12%	475	21.16%	3672	13.90%	1352	16,34%
2022	4100	19.23%	448	23.63%	3918	15.83%	1385	18,37%

Source: The Polish Road Safety Observatory portal (accessed April 2023; author’s elaboration) [12]

Table 2

Hitting a pedestrian – accidents, victims, and injured pedestrians aged 65+ from 2020-2022

Year	2020	2021	2022
Accidents – hitting a pedestrian 65+	1441	1278	1364
Pedestrian 65+ fatalities	224	176	175
Pedestrians 65+ who died on the spot	102	69	80
Died within 30 days 65+	122	107	95
Injured pedestrians 65+	1232	1116	1205
Seriously injured pedestrians 65+	583	489	532
Slightly injured pedestrians 65+	649	627	673

Source: The Polish Road Safety Observatory portal (accessed April 2023; author’s elaboration) [12]

Orthopedic devices such as crutches, frames, supports, and canes are used by people with physical disabilities, as well as people with temporary disabilities who need support in maintaining balance while moving. The choice of the device depends on the physical condition of the person, the condition of their limbs, and the range of movements performed.

Knowledge about such solutions comes mainly from medical equipment catalogs and manufacturers; websites [15]; data available in the patent office; and international databases on trademarks, industrial designs, inventions, and utility models [16, 17]. It is rarely the subject of scientific inquiry and solutions from problem analysis to widespread implementation.

The available literature is more often about orthopedic crutches and describes the methods of moving around with crutches, injuries of people using crutches, injuries resulting from the use of orthopedic crutches (e.g., hand injuries), the description of crutch designs [18-21], or, in general, the needs of PWLP concerning public or individual transport (e.g., drivers with disabilities) [22].

The starting point for the review of orthopedic crutch attachments (caps) (Fig. 1) was the offers of this type of solution commonly available in medical stores in the country and abroad.

Another criterion accompanying this review was familiarization with solutions that are conceptually very different from each other. Selected products were purchased in order to analyze the details of their manufacture and materials. Several dozen solutions were analyzed.

During the review of orthopedic crutch attachments, the following features were distinguished: type of attachment due to the purpose of use, parameters: size, weight, material, size, price, quality and safety markings, and other additional features such as aesthetics and design (Tab. 3). The review shows, on the one hand, that manufacturers try to meet the needs of different users and, on the other hand, that the available variants are too fragmented.

A review of devices dedicated to PWLP, in particular those using orthopedic equipment (i.e., crutches, canes, frames), as well as elements of these devices, such as attachments, shows that their designers and manufacturers do not take into account many features that are important to users, such as material, weight, size, strength, functionality, safety of use, price, quality, aesthetics, purpose. Thus, it

is all the more difficult to talk about meeting the needs of users. Moreover, these devices, if they are not treated as medical devices, are not subject to special regulations and evaluation [9, 15].

Therefore, the design of caps is underestimated, and no attention has been paid to the above-mentioned criteria that should be the starting point for their selection. Users themselves are also unaware of how important this element is.

The analysis of source materials also revealed deficiencies in carrying out functional and technical tests of attachments for orthopedic equipment. Solutions are available, but they are often imported from Asian countries without any documentation guaranteeing quality and safety.

It is therefore worth considering the non-standardized manufacturing process of products intended for people with mobility problems, including users of orthopedic crutch attachments, the final result of which would be a certified product that meets certain standards.

Caps are a replaceable part of crutches. They are an element that wears out, so they must be replaced for the crutch to properly perform its function. Non-slip, easy-to-install attachments are an important element of safe and functional movement with the use of orthopedic crutches on various surfaces and in various weather conditions [24, 25]. There is no perfect product, but the MTI team has set an ambitious goal: to develop one of the best caps available on the market.



Fig. 1. Walking assistance using crutches (attachments marked)  
Source free photos: pl.freepik.com, pixabay.com [23]

## 4. FOCUS GROUP INTERVIEW

### 4.1. Purposes of the study

The purposes of this study concerning the diagnosis of the characteristics of orthopedic crutch attachments and users' opinions on the prototype of this type of device were as follows:

- understanding the terms of accessibility, including road transport, mobility of road users, and road safety, as well as PWLP's attitudes towards these issues;
- learning the experiences of PWLP regarding the use of orthopedic crutches in road traffic in the context of their functionality;
- learning the expectations of PWLP regarding the orthopedic crutch attachment; and
- obtaining PWLP's evaluations of the prototype of the orthopedic crutch attachment developed by the authors.

Table 3

Results of the analysis of orthopedic crutch attachments by significant features

Purpose of use	Depending on the purpose of use, attachments can be divided into standard (universal) attachments; winter versions (e.g., spikes, increased area at the base); specially dedicated (addition to the cap equipped with spikes, self-standing cap); off-road versions (e.g., a shock-absorbing attachment, movable in several planes during use).
Size	Most of the orthopedic crutch attachments available on the market are universal. This allows the user to move in different weather conditions and on different surfaces. The sockets are produced with different hole diameters. Their setting is between 18-22 mm.
Weight	Most models belonging to the standard group are light due to the small amount of material needed for production. The weight reduction is due to the slimmer design of the cap and the lack of additional mechanisms (metal sleeves, metal joints, springs).
Material	Manufacturers use various materials and their composites (i.e., plastic, rubber, natural rubber, metal (structural reinforcement sleeves, reduction sleeves, springs for shock absorption), foam (shock damping), and metal joints (allowing 360° tilting).
Price	The price ranges from a few to several dozen EUR per pair. It would be appropriate to compromise between the cost of producing the cap and the final price of the product, enabling the purchase of the cap to not necessarily be dictated by price.
Quality and safety labels; research results	No information was found on testing the functionality of these solutions. There was also no information on research on their usefulness. No certification information or marking was found.
Design	The caps are produced in various shapes and colors. Attention was drawn to the use of the same type of attachments not only in orthopedic crutches but also in walkers, walking sticks, and trekking poles. An important feature of the cap is its adhesion to the ground, which guarantees the stability of the user in contact with the surface (e.g., the cap cannot collect water from the ground, and dirt and dust should not accumulate in the tread of the cap). No information was found on their ease of use (e.g., putting them on, taking them off, washing them).

Source: Author's elaboration

## 4.2. Methodology

The FGI is a method of conducting qualitative research, which is often used for practical purposes to learn the opinions of groups that meet specific criteria and features that are difficult to estimate numerically. It is also used in the field of road transport. FGIs are met with a skeptical reception from the supporters of survey studies.

A focus group interview is a discussion led by a moderator whose task is to focus the conversation in order to learn as much as possible about the subject of the research. FGIs are also currently conducted using IT tools. Also popular are testing rooms of products or solutions. Interviews allow the opinions and experiences of individual participants to be confronted and consensus to be reached.

The essential features of these interviews are as follows: They are organized in a group (several participants), they are orientated around a topic, the conversation is in-depth (not superficial), and discussions are held (participants do not merely answer questions). A focus group research moderator should have specific interpersonal skills and appropriate education. They do not have to be an expert in the field of research, but they do need to specialize in conducting FGIs.

FGIs are characterized by high interaction – the subjects discuss a topic, come to an agreement, argue, and so on. This makes the solutions and arrangements they reach together more organic than in research conducted using psychometric methods.

During this study, the instructor used some heuristics, artistic techniques, creative thinking (e.g., collages, animations, personification, associations, additions, constructions, brainstorming, elements of

synectics), and other popular methods (e.g., de Bono's "six hats"). These techniques made it possible to uncover the hidden, unconscious opinions and motives behind respondents' actions.

FGIs are conducted in special laboratories equipped with a so-called "preview room" separated by a Venetian mirror and devices for transmitting sessions, making it possible to follow their progress. Such studies are usually observed by their originators. Before the study, the method of communication between the observers and the moderator is established. This gives the opportunity to deepen some issues and ask the respondents questions in a way that does not disturb the discussion.

A single focus session with 6-12 people usually lasts 1.5-2 hours. The course of the study is recorded and then transcribed into a text file. A project based on research using focus groups should involve conducting research in at least two or three groups.

The discussion is conducted according to a developed scenario, which is a tool supporting the work of the moderator containing a list of issues and topics that the group will discuss during the session. The discussion scenario is divided into thematic parts. Recordings (sound or vision) and transcripts of focus sessions are analyzed by experienced qualitative research specialists. These recordings are used to prepare a report [26-28].

Research on the diagnosis of the features of orthopedic crutch attachments and the opinions on the prototype of this type of device was carried out in July 2022 using the FGI method. Two groups of respondents were interviewed. Each interview lasted 1.5 hours and was attended directly by six respondents [29].

### 4.3. Respondents

Participants in the study were people who were constantly moving with the use of one or two orthopedic crutches for a minimum of about one year and had experience using orthopedic crutches in various weather conditions as pedestrian road users. The respondents were residents of Warsaw and the surrounding area. Six respondents took part in each of the interviews. The first interview involved four women and two men, and the second interview involved three women and three men aged 20-65 (the age of 65 is considered to be the borderline between adulthood and old age). The professional work of the respondents did not concern activities for the benefit of PWLP, NGOs, or medical services, and they had never been uniformed service officers.

### 4.4. Selected research conclusions

#### 4.4.1. Accessibility and mobility in the perception of PWLP

The concepts of accessibility and mobility are associated by respondents (Fig. 2) with all road users, including pedestrians; pedestrians with disabilities who use scooters; cyclists; people who use public transport; and drivers of cars, motorcycles, and other vehicles—and their cooperation. The respondents understood the issues of their participation and the synchronization of all participants and elements of road traffic. During the conversation about the mobility of participants in road traffic, associations emerged regarding the difficulties faced by PWLP, including people using orthopedic crutches, which limit their mobility.

#### Synchronization of traffic system elements

**ALL ROAD USERS**  
**PARTICIPATION IN ROAD TRAFFIC**    **lack of various impediments**  
**cooperation of road users**

Fig. 2. Associations of respondents related to the concepts of accessibility and mobility

Source: Author's elaboration

#### 4.4.2. Opinions on safe participation in road traffic

Road safety is an important issue for the respondents. In order to function, live, work, and go to the doctor for rehabilitation, they must be part of society moving on roads and sidewalks, despite the fact

that it is difficult for them. Some of the respondents do not treat safety as a priority issue, and they regard participation in road traffic as a normal circumstance that does not require special attention.

The issues that, in the opinion of respondents, make it difficult for them to participate in road traffic are:

- limitations of efficiency and reaction speed due to their disability,
- too many people and too much momentum regarding the speed of their movement,
- breaking and ignorance of traffic regulations by other participants, and
- poor surface quality (e.g., slippery and uneven pavement or roads), which worsens when weather conditions change).

Respondents mentioned numerous dangers and obstacles they face as road users and described their experiences (Fig. 3). They are exposed to walking on uneven streets and pavement with many obstacles, such as abandoned scooters, garbage, curbs, stairs, and approaches, which threatens their balance and stability and may result in a fall.

The reason for the difficulties faced by the respondents is the presence of too many people on public transport, pavement, stairs, elevators, and in other shared places. The respondents also complained about haste, a lack of caution, and the breaking of rules by other road users (especially cyclists), which reduces their sense of safety.

Orthopedic crutches represent support in everyday mobility for interview participants. They do not treat crutches as obstacles or impediments. To increase their safety, respondents pay attention to the use of appropriate footwear, slow and careful movement, the use of attachments for crutches, and reflective elements.

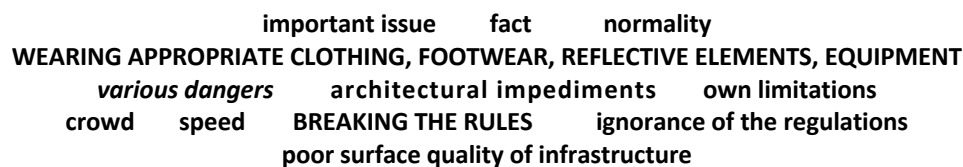


Fig. 3. Associations of respondents related to the concept of road safety  
 Source: Author's elaboration

#### 4.4.3. Experience in moving while using orthopedic crutches and evaluating their functionality

Participants talked about their experiences as users of orthopedic crutches. On the one hand, crutches give them privileges – some traffic rules do not apply to them, and other people give them space, let them pass in queues, help with extra luggage, shopping, etc.

On the other hand, when using crutches in road traffic (as pedestrians), they face specific problems:

- Traffic lights that change too quickly, which prevents their safe passage of the entire pedestrian crossing.
- An insufficient number of seats for PWLP in public transport vehicles and a lack of seats allowing them to rest while crossing the streets, waiting at stops, etc.
- A small number of low-floor public transport vehicles – the respondents have problems with getting on/off the train, tram, or bus when it requires climbing/descending stairs and platforms. Also, not all means of transport are equipped with specialized ramps for disabled people, or using them requires much involvement of the staff or prior notification of the need to use them.
- Attitudes of drivers of private cars, bicycles, and motorcycles who do not comply with traffic regulations and drive too fast and carelessly and public transport drivers who rush according to the scheduled timetable and do not pay attention to the needs of passengers.
- Uneven and slippery surfaces, narrow passages, steep stairs, lack of elevators, underground passages, restaurant gardens make it difficult to walk.

Most of the respondents evaluating the functionality of orthopedic crutches admit that they did not make a conscious choice. Most often, the subjects received crutches previously used by family or friends. They were also not prepared for the fact that they would be forced to support themselves with

crutches for a long time, which meant that they decided to buy crutches that were available at the time and acceptable price-wise.

#### **4.4.4. Selecting orthopedic crutches**

The respondents complained about the small selection of orthopedic crutches and their low availability in rehabilitation or medical equipment stores. They also complained about the lack of information about solutions and possibilities for people who use crutches and the lack of knowledge about the correct way of fitting and using them by people selling crutches or the lack of information about it by doctors who recommend the use of crutches. Some interview participants admitted that it is difficult for them to accept their permanent disabilities, which is why they do not consider changing orthopedic crutches or replacing their individual elements, including attachments. Some people, however, changed crutches when the previous ones turned out to be very non-functional, and the more comfortable crutches were, in many cases, given to them by a family member.

As important features of orthopedic crutches, the respondents mentioned a non-slip handle and non-slip cap, type of elbow brace, adjustment of the crutch to the user (height, weight, method of use), the weight of the crutch and its stability (the lighter and more stable the crutch, the better), the possibility of folding, aesthetics, visibility, and damage resistance.

#### **4.4.5. Selection criteria/features of orthopedic crutch attachments**

A minority of respondents knew about the possibility of replacing the orthopedic crutch attachments. These respondents noticed that the caps wear off with their use. Such information turned out to be interesting for the interlocutors and encouraged them to broaden their knowledge about the possibilities of replacing the elements of orthopedic crutches. The respondents paid particular attention to the use of orthopedic attachments depending on weather conditions. On the one hand, they tend to use different types of attachments, one for rain, another for ice and snow, and another for indoors and, on the other hand, they perceive difficulties in replacing attachments, as it is difficult for them to do it on their own. As important features of orthopedic crutch attachments, the respondents mentioned the appropriate material, anti-slip properties, ease of replacement, durability (low abrasion), stability, and quietness.

#### **4.4.6. Evaluation of the orthopedic crutch attachment prototype proposed by the MTI team**

The respondents approached the evaluation of the crutch attachment proposed by MTI positively and with interest. They particularly appreciated the innovative solution of water drainage, stability, and reflective elements. The respondents spoke of their concerns about how the crutch attachment was installed and whether it fit the crutches they already had. An important aspect mentioned by the interviewees was providing access to information about the planned product. Most of the respondents would be willing to buy it in the future.

### **5. PROTOTYPE MODEL OF THE ORTHOPEDIC CRUTCH ATTACHMENT DESIGNED BY THE MTI TEAM**

Taking into account the opinions and needs of potential users and the modifications they proposed, the authors perfected the prototype of a multi-functional attachment for the orthopedic equipment dedicated to pedestrians, the most important features and schematic appearance of which are presented below. The advantages of the cap, which distinguish it from others, are shown in Fig. 4. Fig. 5 presents a 3D model of the solution [30].

In addition, the following product variants are planned: caps in various colors, caps for crutches of various diameters, caps for winter/summer, and universal versions of caps with the use of various proportions of materials resistant to extreme temperatures. A patent application for product visualization has been filed. The next step is the production of caps according to the design and the developed material



composition, as well as laboratory tests. The attachments produced in the test version will also be evaluated by the target group – pedestrians using orthopedic devices. A positive result of this evaluation process will signify that the product is ready to be launched on the mass market. In 2022, the solution received a gold medal at the International Invention Contest PRIX EIFFEL. The team submitted the product in the safety and accessibility category.

## 6. CONCLUSIONS

The orthopedic crutch attachment is generally a simple and cheap device supporting the safe movement of pedestrians based mainly on an innovative shape (design) and material. The use of the appropriate attachment enhances the sense of stability of the user's body and the ability to rest firmly on the crutch. Contrary to popular belief, preparing a high-quality product that meets the expectations of the recipient is not an easy task.

Surprising findings resulting from the implementation of these stages of work (which are generally easy to solve) concern incorrect or lacking communication. They indicate three gaps related to the activity/cooperation of users, manufacturers of orthopedic equipment, and decision-makers:

1. Gaps regarding public information and dissemination of knowledge about personal solutions addressed to PWLP.
2. Gaps regarding the design/production of PWLP-supporting devices, taking into account the users' needs.
3. Gaps regarding the monitoring of public space and the introduction of simple facilities addressed to PWLP, the fulfillment of which would improve the functioning of this group. Physicians, in particular orthopedists and physiotherapists, should be the link between them.

The present article was created as a part of the project entitled "Opracowanie rozwiązań dedykowanych pieszym poruszającym się przy użyciu kul ortopedycznych w kontekście badań potrzeb tej grupy uczestników ruchu drogowego w zakresie dostępności i funkcjonalności elementów wspomagających ich poruszanie się oraz poprawiających ich mobilność i bezpieczeństwo" [In Polish: Development of solutions dedicated to pedestrians using orthopedic crutches in the context of research on the needs of this group of road users in terms of the availability and functionality of elements supporting their movement and improving their mobility and safety]. It was financed by the Motor Transport Institute.

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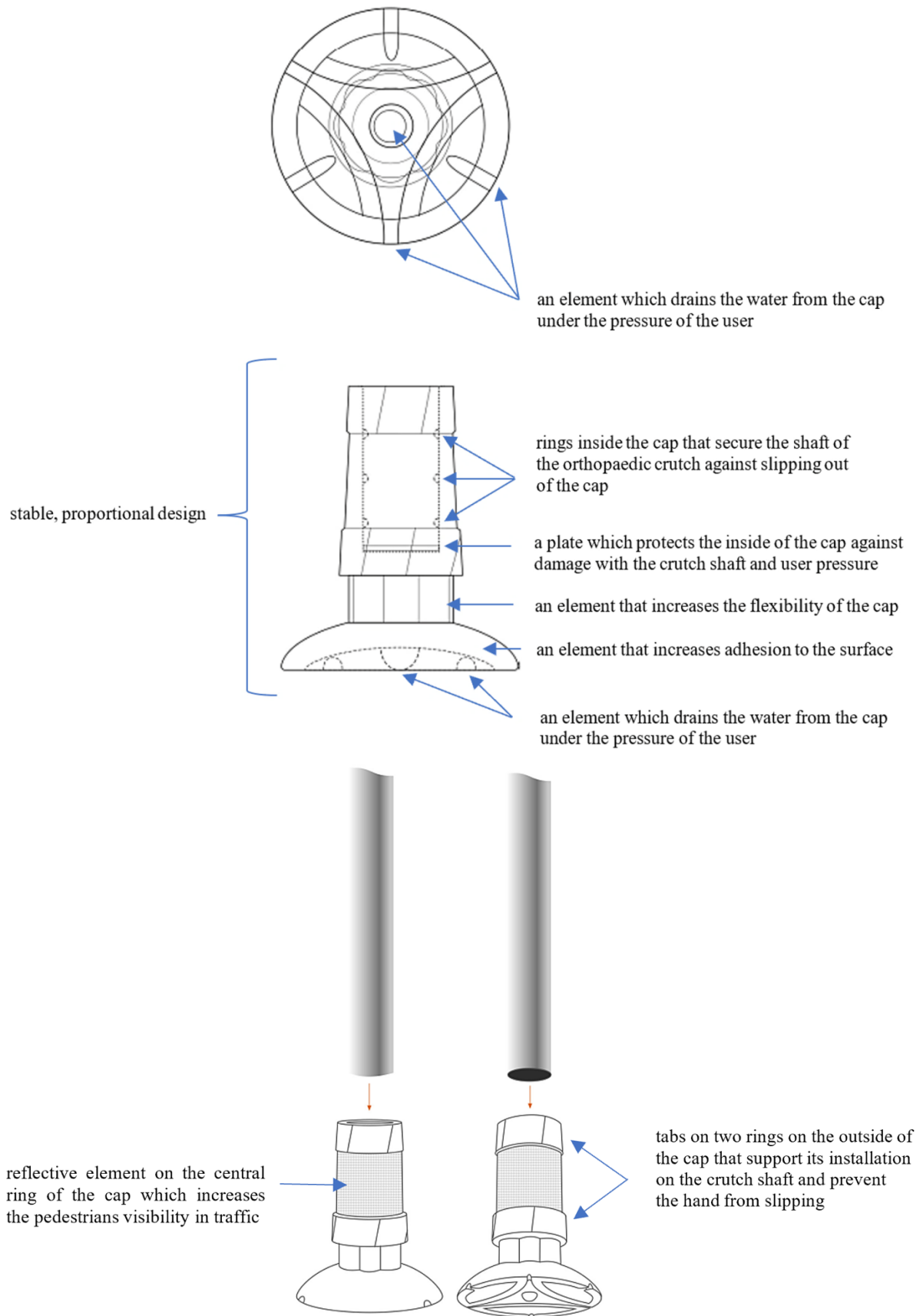


Fig. 4. Prototype of the attachment to the orthopedic crutch of the MTI team  
 Source: Author's materials

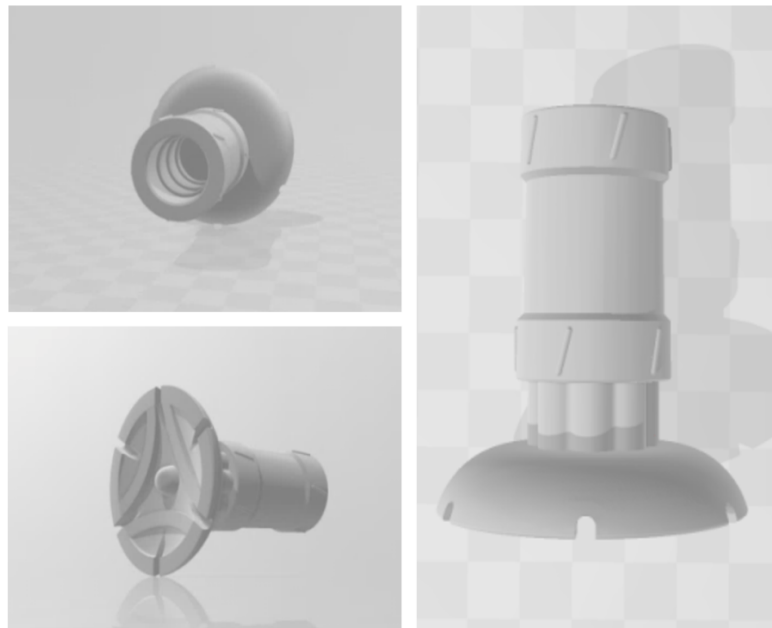


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Source: Author's materials

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