Adjustable Grab Bar

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Abstract (237 Words)

One of the most common assistive devices for people who use wheelchairs is the grab bar. These are railings that a generally mounted to the wall in a fixed position in public accessible washrooms to help the user move from their wheelchair onto the toilet. The non-personalized nature of the classic grab bar can cause people to lose faith in their ability to transfer themselves to the toilet without falling, getting winded, or embarrassed. Brett Lyons, founder of Your Mobility Innovations and person living with cerebral palsy, partnered with Queen's Biomedical Innovation Team (QBiT) to develop an adjustable grab bar to improve the confidence of individuals with disabilities when using the washroom and to reduce the number of shut-ins in the community. Among other requirements, the product was to be adjustable in height and require only limited dexterity to use while able to support up to 400 pounds. The final design implemented the use of an "S" shaped bar along with a hand crank actuated gear train consisting of a rack and pinion, worm gear, and bevel gears. A full-scale prototype of this design was created by QBiT and tested by Brett. Future work based on user feedback would include reducing bar wobble, creating a custom hand crank, and covering the rack teeth. The prototype cost $2650 to produce, but would ideally be sold for $1500, resulting in a possible $2,314,950 of profit for Your Mobility Innovations.

Background & Problem Statement

About 4.4 million people, or one in seven Canadians, have a disability. That number is expected to grow to one in five in the next generation of Canadians. More than 8 of 10 individuals with disabilities use aids and assistive devices [1]. One of the most common devices used to facilitate movement is the wheelchair. In Canada, there are standards and acts such as the Accessibility for Ontarians with Disabilities Act, 2005 (AODA). The goal of these are to remove barriers that prevent access for persons with disabilities. In washrooms, a "one-size-fits-all" approach is used for many aspects, such as grab bars to add accessibility to washrooms. There are differences between Provincial Codes and Canadian Standards, however they are all similar for the locations of both the grab bar on the wall beside the toilet and the wall behind the toilet. For each location, the grab bars have a range of height from the floor, height above the toilet, and lengths. These grab bars are fixed and do not allow for any adjustment to account for the differences in users' sizes.

The non-personalized nature of the classic grab bar can cause people to lose faith in their ability to transfer themselves to the toilet without falling, getting winded, or embarrassed – all this ultimately resulting in people becoming shut-ins. This problem was experienced first-hand by Brett Lyons, who has cerebral palsy; he took it upon himself to act to change this norm. Brett and his business partner, Dylan Holden, have founded Your Mobility Innovations and came to QBiT with the task of designing and prototyping an adjustable grab bar. The goal of this design is to allow the user the ability to determine the appropriate height of the grab bar for themselves through an adjustable grab bar system.

Design Criteria

The client, Your Mobility Innovations, provided QBiT with the initial design requirements, which were expanded, and are listed below.

Client Design Requirements

- Utilizes an automatic or easy release locking mechanism
- Allow users with limited dexterity to use to the full potential
- Strong enough to support 400 pounds in all directions
- Adjustable to a variety of different heights

Additional Design Requirements

- No removable parts
- Adjustable with one hand, either hand
- Made up of non-corrosive materials

Preliminary Designs

There were many options considered for the solution of the adjustable grab bar. The design began with the grab bar being supported between two vertical guides that were mounted to the wall. These concepts incorporated either a discrete pin-locking mechanism or a dual ratchet and crank mechanism. Both concepts allowed for adjustment in both height and angle but were limited by: their ease of use because two hands or two adjustments were required, and their safety because neither would lock automatically and could result in a fall. The possibility of using a cable and crank was also discussed but discarded due to similar issues. Some of the initial concept sketches of the preliminary designs outlined above can be seen in Figure 1.

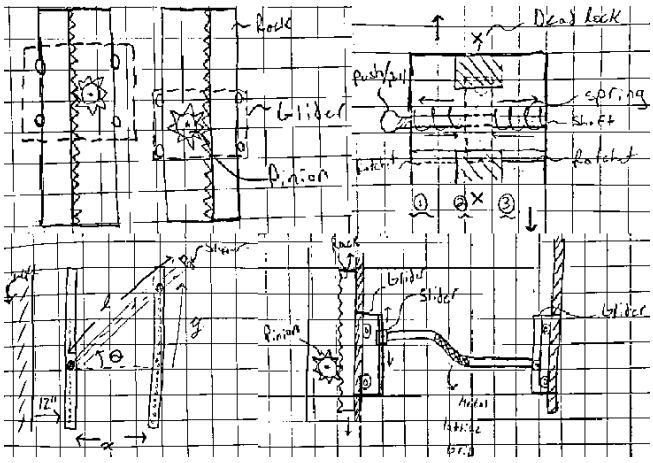

Figure 1: Preliminary design sketches

Final Design

Eventually, it was decided that adjustability in angle was not necessary if an "S" shaped bar, shown in Figure 2, was used. This bar then only required a single adjustment mechanism which could be mounted to any location along the bar. The center of the bar was chosen as the mounting location to reduce the moment acting on the joint when loaded.

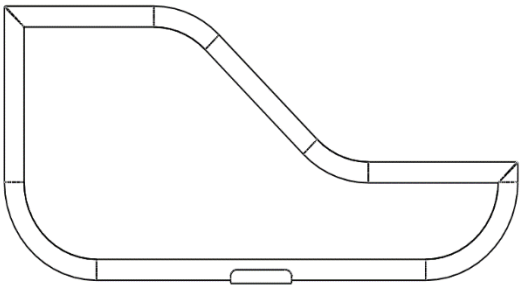

Figure 2: "S" shaped bar

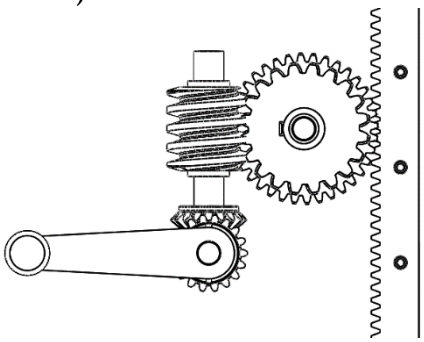

Figure 5: Adjustment gear train

The chosen mechanism for adjustment was a single hand crank and a gear train involving bevel gears, a rack and pinion, and a worm gear. The rack and pinion is the ultimate mode of adjustment: the rack is mounted directly to the grab bar on its lower half and is fed through a sheath with a bearing inside. The pinion protrudes through the sheath to interact with the rack. In parallel with the pinion is the worm and worm gear. This setup allows for a low gearing ratio, resulting in low required adjustment force. Another feature of the worm gear is that it can be only driven by the crank and worm (i.e. rotation of the worm causes rotation of the worm gear, but the worm gear cannot cause rotation of the worm). In this way, the worm gear acts as an automatic locking mechanism and eliminates the risk of lock slipping and the resulting potential of the user falling. The bevel gears allow for the crank to be positioned in the most ergonomic and low-profile position, which is perpendicular to the worm gear. This gear train in shown in Figure 3.

Figure 4: Final prototype

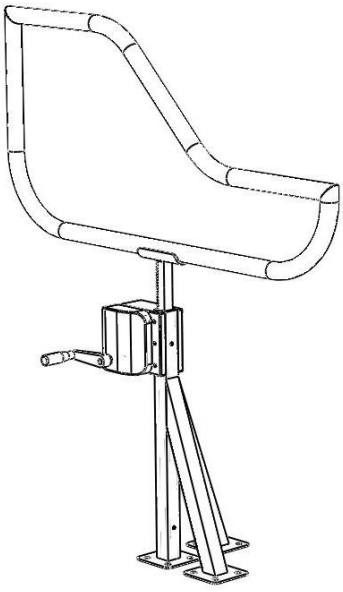

Figure 3: CAD model of design

Finally, the grab bar was designed to be mounted to the floor using a tri-pod type stand. Floor mounting gives the most flexibility in where the grab bar can be mounted with respect to the toilet and is more secure and easier to install than mounting to a wall. Figure 4 shows a line drawing of the design and Figure 5 shows the resultant prototype.

Qualitative Testing

To this point in time, testing for this device consists of a person with cerebral palsy making three transfers per day. In each transfer the user adjusts the height from the bottom, to their desired height, then back down after use. 21 tests were completed over the span of one week. Table 1 below shows the key qualitative results and observations from this testing.

Table 1: Qualitative results for main test criteria

Criteria	**Adjustability**	**Crank**	**Strength**	**Grip Surface**
Rating	9/10	6/10	7/10	10/10
Comments	• Getting easier to adjust after repeated use • Large adjustment area • Becomes loose towards the top end would not result in a fall, but it could result in the user feeling unsafe • Bar should not come up enough to come out of base	• Flip away crank works well • Handle could be larger and easier to grip • Handle can be slippery (pattern or finger grip simple solution)	• Lots of movement in the bar when pressure is applied that would need to be tightened up to provide the confidence we want the users to have • The bar seems unsteady at times, but never fails	• Large grip surface • Lots of options allowing for user choice • No sharp edges • Easy grip diameter

Major takeaways from this result suggest that the product works well and offers all benefits of standard grab bars while allowing for the further benefit of allowing users to fit it to their specific needs. Future work would include tightening some tolerances on the bearing to reduce bar wobble, creating a custom hand crank with a larger and textured grip surface, and covering the rack teeth with a telescoping sheath.

Cost Breakdown

Table 2 below shows a cost breakdown for production of the prototype.

Table 2: Cost breakdown of final prototype

Item	Cost ($USD)
Gearing	335
Bearing	25
Post-Machining & Fabrication	2250
Other Raw Materials	40
Total	**2650**

Market Economics

High quality certified grab bars can cost hundreds of dollars each, and the inadaptability of these products often results in the installation of two or more. Property developers are thus spending upwards of one thousand dollars of products that are not working. This new adjustable grab bar is intended to be sold for around $1500 each, capitalizing on a market that is accustomed to paying a premium for products that work. In consultation with machine shop professionals it is likely that in high quantities and with some design alterations, the production cost of this grab bar could be lowered to the $1000 mark.

The target market for this product is large living places like hotels, and retirement homes. There are 61,732 of hotels in Canada and the USA [2], [3]. Each one of these buildings requires one-to-two accessible bathrooms. This results in a potential national market size of $138,897,000. A conservative 5% market capture results in the potential for $6,944,850 of revenue and $2,314,950 of profit. This market will only grow in the near future because of the aging population in the USA and Canada.

Significance

Clearly, a product like the Adjustable Grab Bar would benefit the lives of thousands of individuals across Canada and the United States. Owners of hotel chains will have demand for this product to: increase their customer base as shut-ins will be able to use their facilities, and improve customer satisfaction. Further applications for this product could include hospitals, public recreation areas, and children's treatment centers.

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Client

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