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Chair for the bath of Quadriplegics

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Abstract: The following project involves a study about the hygienic process in the bath of quadriplegic people. The main problem of the currently available equipment is the caregiver's necessary effort during the act, since the patient does not present movement of the upper and lower limbs, thus implying a total dependence of the person with quadriplegia on his caregiver. The research proposes a remodeling of the most common model of bath chair used in the domestic and hospital environment. The treated device allows the inclination of the sanitary seat coupled to the chair using the support of a manual hydraulic piston, facilitating access to the patient's intimate areas and, consequently, better hygiene—this feature located below the seat, coupled to the frame on the front. Also, the supports for the patient's feet and arms modeled, allowing the abductor movement of the lower and upper limbs, contributing to the visualization and access to the areas, emphasizing that these require careful cleaning, as they function as an outlet for liquids and excrement of the human body. It was possible to remodel the bath device in Autodesk Inventor 2018 software. The material selected for the construction of the structure was Steel 1020, which was selected based on the physical, chemical, and biological agents that could come into contact with the chair. The structure is resistant to safely support the patient and not to suffer significant wear over time.

Keywords: Quadriplegics, Bath chair, Assistive Technology.

I. INTRODUCTION

The occurrence of an accident or aggression that affects the spinal cord at the level of the cervical vertebrae can cause a traumatic injury. This medical condition is known as quadriplegia [1]. When a person is affected by this situation, his whole reality faced a series of challenges.

The lack of sensitivity and motor skills below the level of the lesion, together with the loss of sexual function and control of the sphincters, brings with it the finding of a changed body [2]. This irreversible state requires the help of not only specialized equipment, but also family members or contracted professionals. The current market shows a trend towards studies dedicated to the development of Assistive Technologies. This is due to the growth of a society tolerant of differences and concerned with the inclusion of disabled people in the social/private sphere [3].

In addition to the impact that the situation has on the individual's personal life, the family environment changes its economic and social organization. Because of the need to accompany the person with quadriplegia, a family member commonly becomes a primary caregiver, helping in various activities considered necessary [3]. The impact of stress caused on the caregiver is manifested through physical and psychological problems, directly affecting the type of care that the patient starts to receive. The improvement of products also focused on the caregiver can improve not only his quality of life but also the person with quadriplegia and the rest of the family [4].

The term Assistive Technology is TA is defined as all the resources and services that contribute to providing or expanding the functional abilities of people with disabilities. Consequently, it helps to a partially independent life and progressive inclusion in society [5].

However, even with the variety of equipment available for home and outdoor use, there is still difficulty in adapting specific individuals to the options presented. Because of this fact, it is justified to study the particularities of each one so that it becomes possible to facilitate the use and implementation of technologies in their routines [6].

Another relevant aspect of being addressed is the psychological state of the disabled person. It is necessary to emphasize that aid equipment must not harm the moral integrity of those who submit to its use. The provision of a system that preserves the patient's integrity, but at the same time allows for proper hygiene is essential in a product that seeks to improve the quality of life [7]. Bath chairs are useful for facilitating the practice of bathing [8]. Manufacturers manufacture bath chairs with an aluminum or steel structure, a toilet seat

attached to a metal support structure, wheels that differ in the size of the rim and brakes, and the non-variation of dimensions [9].

Projects developed using 3D modeling software, simulation, and computational support are suitable for Assistive Technology (AT) [10] or improvements in hospital devices and devices and to support people with disabilities [11-12].

II. BIBLIOGRAPHICAL REVIEW

The complete or partial alteration of one or more segments of the human body, causing the impairment of physical function, in the form of paraplegia, paraparesis, monoplegia, monoparesis, tetraplegia, tetraparesis, triplegia, triparesia, hemiplegia, hemiparesis, ostomy, amputation or absence of a limb, cerebral palsy, dwarfism, limbs with congenital or acquired deformity, except for aesthetic deformities and those that do not cause difficulties for the performance of functions [13].

Understood as a change in the body that causes difficulties in moving people and prevents them from participating in life independently. Or as a handicap, resulting from a compromise or disability, which limits or impedes the individual's motor performance. Thus, physical or motor disability can be considered a disorder of the anatomical structure or function, which interferes with the individual's movement and locomotion [14].

Spinal Cord Injury or Spinal Trauma (ST), as described in medical language, is a severely disabling neurological syndrome. ST presents the changes in motor skills, superficial and profound sensitivity, and neuro vegetative disorders of the body segments located below the injury since it is the spinal cord that functions as a communication route between the different parts of the body and the brain, systemically controlling the organism [15].

The vast majority of people affected by such an injury, now in a wheelchair, need to undergo a rehabilitation process that helps them reach their best physical, psychological, and social potential. Rehabilitation is a concept that must involve the entire health system and actively integrate or reintegrate into society the person whose capacity is impaired. Among the goals desired through rehabilitation are: increased independence, decreased length of stay, and, mainly, improved quality of life [15].

The degree of disability and the extent of the sequelae, in spinal cord injury, vary according to the level, the degree, and the time of injury. Thus, lesions located in the thoracic, lumbar, or sacral levels trigger paraplegia, causing motor and sensory impairments in the trunk and legs or only in the legs. And lesions at the level of the cervical spine lead to cases of quadriplegia, with impairment of physical integrity in general. As for the degree of injury, the transverse and longitudinal plan included. In the transverse plane, it can be of complete degree, where all active movement and sensitivity below the injury are absent. In the incomplete degree, it is characterized by the existence of the preservation of some motor skills and sensitivity below the level of the damage. In the longitudinal plane, several or all segments below the level of the lesion are involved. As for the time of diagnosis of the injury and the beginning of effective clinical procedures after spinal shock, emergency care is essential, as it determines the possibility of a better prognosis for recovery [16].

Tetraplegia refers to the impairment of the motor and sensory function of the cervical segments of the spinal cord due to the damage of neural elements within the spinal canal by a complete injury. It also results in impairment of the functions of the upper limbs, trunk, and lower limbs, in addition to the pelvic organs. Among the most common consequences that affect individuals with high spinal cord injury are detrusor areflexia, autonomic hyperreflexia, loss of locomotion or means of transfer, pain, spontaneous breathing, contractures, muscle atrophy, heterotopic ossification, pressure ulcers, osteoporosis, in addition to affective disorders and quality of life [17].

III. MATERIALS AND METHODS

The project emerged as an alternative idea to the products available on the market, especially the one offered by the *Sistema Unico de Saúde* (SUS). A visit occurs to the Association of Physically Disabled (ACADEF), where the social and physiotherapeutic care of physically disabled people takes place. Through this, it was possible to talk to the person in charge of the area and discuss ideas that would add useful characteristics for caregivers of people with quadriplegia. With the appearance of possible changes in the structure of the existing model, the group decided that, for a thorough understanding of the problems that occur during bathing, it would be necessary to interview a quadriplegic patient and his primary caregiver. Two questionnaires have been prepared to gain different perspectives on the problems.

Therefore, a young quadriplegic was recommended at ACADEF, who agreed to appear at the interview accompanied by his father, who assists him in hygienic activities through the use of the bath chair provided by SUS. Although there were positive comments about the current structure, difficulties were reported that contributed to an arduous process in the interaction between the caregiver and the physically disabled. As a result of the process, the person responsible for the young man expressed pain and discomfort due to physical effort and poor posture, which can harm the spine and other members of the body.

As a result, the group formulated hypotheses for improvements to the device, which would contribute to a more comfortable activity for the person with quadriplegia and their respective caregiver. A virtual prototype in the Autodesk Inventor Professional 2018 software that would meet the needs exposed by the person with quadriplegia and his caregiver, enabling greater ease in basic hygienic operations.

For this, bibliographic sources were consulted to understand the patient's condition, together with a study on the existing models and their limitations. Also, the dimensioning and choice of materials was made to support the physical efforts and chemical and biological agents present in the activity. For the theoretical basis of the work to be possible, it was necessary to visit and accompany professionals at the ACADEF institution, together with reading scientific articles and works whose central theme is accessibility and quadriplegia. Besides, technical books specialized in the design of prototypes for humans were interpreted, making virtual prototyping in software possible.

The presence of a qualified scientist during the interview was essential since the group was not prepared to deal satisfactorily with issues about the privacy of the patient and his family. For this, there was the presence of a professional in the social service area who monitored the progress of questions and answers, ensuring that they were asked in the most dignified way possible.

Autodesk Professional Inventor 2018 software was used for the design of the prototype and the simulations that involve it. Previously to the design and dimensions, there was a sketch of how the structure should be and what features could be added. This was based on the model that receives focus on the project, the "Standard Bath Fixed" bath chair, commonly used in hospitals and home environments. Although there are models that provide a better experience to the patient and caregiver, as is the case of the Standard Bath Plus Reclining, the model mentioned above is frequently used, given the easy access through third parties and the distribution made upon request to SUS. Through this sketch, the researchers stipulated the addition of features that would facilitate the interaction between the person with quadriplegia and the caregiver, which would later be discussed with the case that served as a basis for the design of the structure.

After using questionnaires for the patient and their caregiver, the need to remodel the supports was evident to allow the abductor movement of the upper and lower parts, as these require the positioning of the individual being cleaned to enable access to regions like the anus and the armpit. As reported by the caregiver, this process calls for physical efforts that can harm joints and the spine, causing pain and discomfort. Based on the report, the researchers developed a system of articulations that would facilitate the access previously treated. The first joint designed located at the junctions of the base of the chair with the rest of the structure. On both fixing bars of the toilet seat possibles to tilt up to 22 ° concerning the backrest (Fig. 1).

Figure 1. Virtual Shower Chair Prototype.

For the projected bath chair, a circular steel tube with a diameter of 30 mm and a thickness of 4 mm was used. Circular tubes were chosen because they are resistant to the demands that will be imposed on the structure, in addition to loose issues and the ease of fixing elements. The structure will be 45 cm wide and 50 cm long, according to the measurements of the quadriplegic patient.

For the design of the chair, circular steel tubes of 30 mm in diameter and 4 mm in thickness were also used. The chair will be 50 cm long, based on the linear measurement of the quadriplegic's hip and 45 cm wide,

which is the length of the bone to the quadriplegic patient's knee. It also has a height of 60 cm, as it is the measurement of the patient's trunk. This can be tilted 22 ° without compromising the structure of the base and the base. The backrest will be upholstered and covered with leather, to increase resistance against water and offer comfort to the patient.

Figure 2. Shower chair tilted at 22 °.

For the seat, the measurements of the patient's hip, 41 cm, and the femur, 50 cm, were considered, but the seat is also standardized, according to each company. The seat material will be polyester due to its high durability and ease of cleaning. This support was dimensioned considering the measure of the elbow to the quadriplegic's wrist, of 25 cm, plus the length of the hand, of 11 cm, totaling 36 cm for this dimension. The armrests will also be made with steel bars and upholstered for comfort.

The backrest was dimensioned 254 mm long, 159 mm high, and 30 mm wide, which will be upholstered and covered with leather, to increase resistance against water and offer greater comfort and safety for the patient. The fixation of the patient will be done through a pectoral belt for wheelchairs, adjustable and made of nylon that will be attached to the structure of the chair, with the aim of involving the patient and keeping him fixed in it.

Stress simulations were performed in Autodesk Inventor Professional 2018 to obtain the results on the validity of the structure. A force of the person with quadriplegia was 600 N. A vertical force of 300 N was added to the sidebars of the base of the chair. At the bottom of the hydraulic jack, a force of 150 N was applied to stipulate the weight of the stud with a safety factor. A bar of 800 N was used to the bar positioned above the hydraulic piston of the jack to simulate the force that the jack will make to raise the chair to 22 °. Also, a force of 500N was added to the support bars that limit the angle of the chair to stipulate the weight of the person with quadriplegia plus that of the chair structure, when tilted, so that the chair does not tip over and the bar does not flicker.

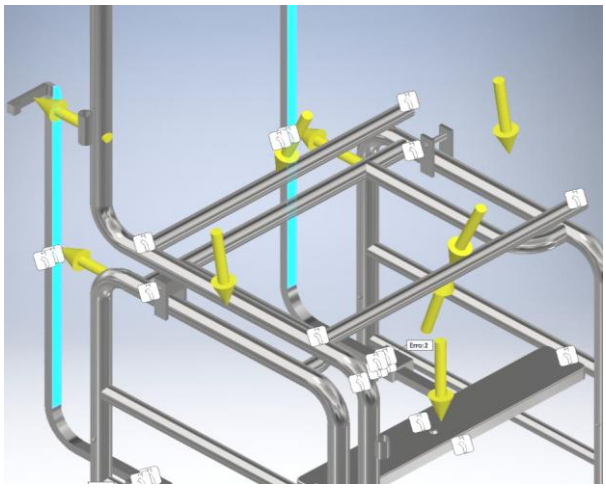

Figure 3. Forces implementation.

From the stress simulation, it was possible to obtain the results on the structure's viability. The maximum displacement that the structure will have is 0.1871 mm, located at the point of application of the hydraulic cylinder of the jack on the bar that will propel the chair to 22 °. The maximum normal stress will be 86.01Mpa, located at the ends of the bar at the front of the structure.

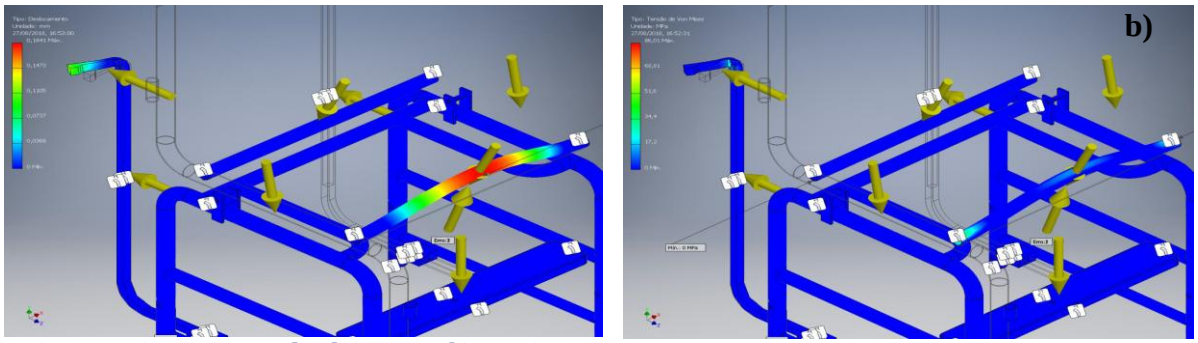

Figure 4. a) Maximum displacement; b) Maximum normal stress.

It was possible to verify in the structure analysis report, some material properties. Considering that the flow resistance of the material is 207 Mpa and the maximum tensile strength of 345 Mpa, it can be verified from the value of 85.01 Mpa for the maximum stress, that with the load applied to the structure it will not deform and it won't break. As the value obtained is considerably low to the structure's properties, it is still possible to use other tetraplegics, with different heights and weights, to use the construction. Besides, the value obtained for the maximum displacement is negligible.

IV. CONCLUSION

Through the analysis of the structure, it was possible to establish the limits of the functionality of the virtual modeling. With the actuation of the manual hydraulic cylinder, the desired inclination can be reached safely and without great efforts. Such an addition to the structure provides improved visualization of the patient's intimate area, avoiding the excessive inclination of the caregiver during the hygienic process. The system of joints implemented to allow the abductor movement of the supports for the arms and legs of the patient fulfills the desired. Access to areas that previously required effort from the caregiver, such as locomotion of the patient on the chair, represents less of a challenge for bathing. Excrement residues and body fluids removed using effective cleaning, a result of the ergonomics that the remodeled structure provides.

The selection of materials theoretically resists contact with substances that will occur during the bath. The elements mentioned above were taken into account, as these can damage the structure and, consequently, impair the safety of the equipment. The addition of a seat belt to the chair certifies that the individual will not fall during the act. This increase happened as a suggestion of the case studied, because, although it does not represent a significant increase in the real safety of the patient, it contributes to his psychological comfort, since he will feel more comfortable with the situation.

The stress analysis that occurs in the Autodesk Inventor Professional 2018 software showed that the device could be safely manufactured in the future, continuing the project. The tests ensure that the chair supports the hydraulic cylinder and the cargo transported, that is, the patient in conjunction with the structure made mostly of steel.

Since the researchers were able to plan equipment capable of meeting the objectives of assisting the caregiver during the bath of people with quadriplegia, the project intends to build the physical prototype of the structure as a sequence. Furthermore, considering that the tests done with the chair were only in a virtual environment, there is an intention to test the device in an environment that simulates the practice of bathing.

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