TRANSHUMERAL PARALLEL PROSTHESIS

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Abstract. (Different stages for the design of a transhumeral prsothesis are described in this paper). The design and construction of a new prosthesis with parallel topology for above elbow replacement is proposed in this work. This prosthesis has 4 active movements, 3 in the elbow and one for grasping. The active articulations correspond to grasp, prono-supination, elbow flexion and humeral rotation. Linear actuators were designed and built to fit the force and span necessities of the prosthesis. The parallel topology allows at least two linear actuators to simultaneously participate in each one of the three active movements of the elbow, while the actuators that don't participate in each movement will remain rigid giving support to the structure. This way, the proposed prosthesis does not require an exoskeleton, diminishing the weight and improving the use of available space.

Keywords: Prosthetic elbow, linear actuator, humeral rotation, endoskeleton, upper limb.

I INTRODUCTION

Up to date, most notable prostheses have only one active movement in the elbow i.e. Modular Arm of Edinburgh [1], the Utah Arm [2] and the Boston Elbow [3]. These prostheses can be adapted with an electric wrist rotator and with an electric hand normally made by the German company Otto Bock. But, which movements are really useful for a person with transhumeral amputation? What is the maximum weight accepted in prostheses? With these questions in mind, a brief review of the range of movement of the upper extremity during everyday activities is presented. This analysis is helpful for designing an optimized prosthesis in weight and electrical consumption, but above all things this analysis is helpful for designing a prosthesis with really useful movement capability.

The shoulder is the human articulation with most mobility. In the present work, the rotation of the humerus around its mayor axis, what is known as humeral rotation, is the only interest. While the transhumeral stump is able to transmit lateral and frontal abduction-adduction movements to the prosthesis, it is unable to transmit rotation around its long axis. Esparza [4] and Ivco [5] have measured humeral rotation involving 51 daily activities in subjects with sound arms. While the humerus is capable to rotate 180º around its long axis, Ivco[5] has found that only 20° of external humeral rotation and 40° of internal humeral rotation are necessary for most daily tasks. For this reason, some prostheses have a friction plate for rotating above the elbow. Prostheses without humeral rotation flex the elbow in a fixed direction toward the mouth.

The elbow is the joint made of three bones: humerus, radius and ulna. The elbow is a trocoginglimoid articulation; this means that it is a dual articulation: ginglimoid and trocoid. The junction of the humerus with the radius and ulna allows the flexion of the elbow like a hinge. The junction of the radius around the ulna is the trocoid joint and it allows the prono-supination.

The elbow flexion in a sound arm is about 140º to 146º but most daily activities can be accomplished with only 100º of flexion (from 30º to 130º) [6]. The American Academy of Orthopaedic Surgeons [7] reports a mean pronation and supination of 70º and 85º, respectively, resulting in a prono-supination span of 155º. Chao [8] and Murray [9] have determined that for common activities a pronosupination span of 100º (50º for pronation and 50º for supination) is enough.

The wrist has two degrees of freedom (DoF), flexion-extensión and abduction-adduction. Nordin [10] have found the normal wrist flexion is about 85º to 90º and the wrist extension is about 75º to 80º. The total arc of radio cubital deviation is about 50º, being 15º to 20º the contibution of radial deviation and 35º to 37º the contribution of cubital deviation. Volz [11] reported that movement loss in the wrist does not seriously limit accomplishment of daily tasks. Volunteers were asked to develop different common activities with their wrists immobilized at different angles of flexion-extension and abduction-adduction. The best performance of the volunteers was with the wrist immobilized with an extension of 15º and a cubital deviation of 20º.

II MATERIALS AND METHODS

Once justified the span of mobility of the transhumeral prosthesis is necessary to find the appropriate materials for its construction.