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A review on surgical instruments of knee arthroscopic debridement and total hip arthroplasty

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Abstract

Knee arthroscopic debridement, total hip arthroplasty(THA) and artificial femoral-head replacement are the major treatments for joint diseases, and they have a high degree of dependence on various complicated surgical tools. Structure design, manufacturing precision and cutting performance of surgical tools are important factors that influence the success of operation. This review introduces the arthroscopic cutting tools, acetabular reamers, starter awls and femoral broaches which are used in arthroscopic debridement and THA, And this review also analyzes structural characteristics and cutting mechanism of those surgical tools, and point out design principles, problems and research directions in the design and manufacture.

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Keywords: Knee arthroscopic debridement; Total hip arthroplasty; Surgical tools

1. Introduction

Knee joints and hip joints are the most complex and stable structure of human body, and play an important role in human's daily activities. Knee joints injuries, degenerative osteoarthritis, rheumatism and osteonecrosis of the femoral head are the most common orthopedic diseases caused by the heavy load in activities and sports. These diseases would change the stress distribution of the joints and cause functional limitation and loss. Knee arthroscopic debridement, total hip arthroplasty and artificial femoral-head replacement are the major treatments for advanced knee joint and hip joint diseases.

Arthroscopic minimally invasive surgery with its small incision, less trauma, less scar, faster recovery and less complications, has gradually become a routine diagnosis and treatment in orthopedics. As shown in Fig.1. Total hip arthroplasty and artificial femoral-head replacement are to cut the broken joint and replace it with artificial joints which have good biocompatibility and mechanical properties. The operating procedure of THA is shown in Fig.2.

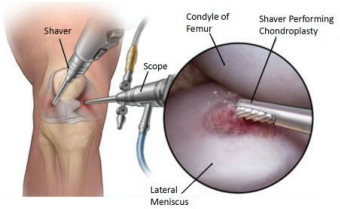

Fig.1 Arthroscopic minimally invasive surgery

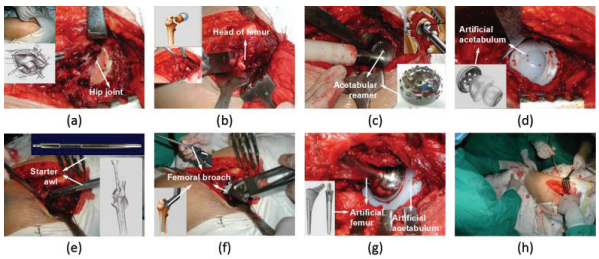

Fig.2 operating procedure of THA

(a)Exposure and division of articular capsule; (b)Removal of the femoral

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head; (c)Acetabulum reconstruction; (d)Implantation of artificial cup; (e)Preparation of the femoral canal; (f)Insertion of femoral broach; (g)Artificial joint checking; (h)Suture.

With the development of society, patients increasingly want to use advanced surgery to improve the recovery after operation and postoperative quality of life. The practical experience of doctors, cutting performance and structural design of surgical tools are critical factors for a successful operation. The selection and application of surgical tools are based on the clinical experience of doctors and recommendations from medical device companies, and there is no uniform evaluation index. There is a phenomenon that the market of medical instruments is monopolized by the famous companies such as Strtker, Smith & Nephew, Synthes, Johnson & Johnson, Richard Wolf and so on. In the field of medical instruments, relevant researches focus on different instruments' performances such as cutting rate and tissue damages in vitro or vivo experiment. However the results of these researches are lack of consistency because of the various parameters in experiment., and the evaluation indexes are not yet clear.

Because of complexity in operation, the dependent degree on surgical instruments is much higher than the traditional surgery. The commonly used surgical instruments have characteristics of various type and exquisite structure. Its reasonable design, manufacturing and use will affect directly the efficiency of the biological vivo tissue's removing and the degree of cutting fracture properties, and have a great influence of the quality of surgical results and postoperative rehabilitation. This review summarizes the research progress on the structrue, mechanism, manufacturing and reliability of surgical instruments in arthroscopic minimally invasive surgery and THA, pointing out the main technologies problems existing in those surgical instruments as well as the main directions of future research.

2. Arthroscopic shaver and bur

Arthroscopic shaver system plays a key role in Knee arthroscopic debridement. It can help clinicians cut massive tissue in a short time. Most of these systems are similar in structural design, and they all consisting of hand piece, core powered instrument driver, footswitches and arthroscopic shaver. As shown in the Fig.3. Hand piece can be controlled by core powered instrument driver or footswitches.Connecting suction device is used to absorb the chips out of knee joint during the surgery.

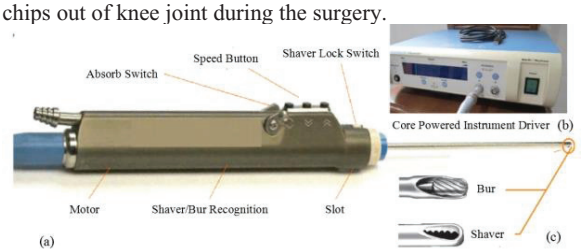

Fig. 3 The arthroscopic equipment

(a)Hand piece; (b)Core powered instrument driver; (c)Cutting tool

2.1. Structure and mechanism

Arthroscopic system has three working modes including counter-wise, counter-clockwise and oscillation. Its rotating speed is about 100-10000rpm. Compared to the other two working modes, the cutting rate of shaver in oscillation rotation modes is more higher. Both shaver and bur consist of stationary elongated outer and rotating elongated inner tube(Fig.4). Those tubes are made of stainless steel and its diameter is about 1.9-5.5mm. There are cutting windows at distal tip on the outer tube and inner tube. Arthroscopic shaver with inner window has a plurality of teeth positioned along the distal cutting edge. Due to the connection between hand piece and suction device, the cutting window of inner tube would form subatmospheric pressure and absorb the tissue close to the windows. And then the cutting teeth can easily penetrate into tissue and prevent ejection of tissue from the cutting window during closure. The outer tube keeps the non-surgical site away form the inner cutting window and has a protective effect on it. The arthroscopic shaver is used to remove the fragments of the denatured cartilage and cut off the dissociate cartilage. Otherwise the shaver can be used for aggressive meniscal trimming, joint debridement, plica and synovium removal. Burs have several spiral curve cutting edges and it is useful for aggressive bony site preparation, intercondylar osteophytes resection, cartilage and osteochondral debridement. After debridement, the nidus should be cleaned by large amount of saline. Various shape of cutting teeth and cutting edge can be found in different version shaver and bur. Each shape of cutting edge and structural parameters has its own application and cutting object.[1-5].

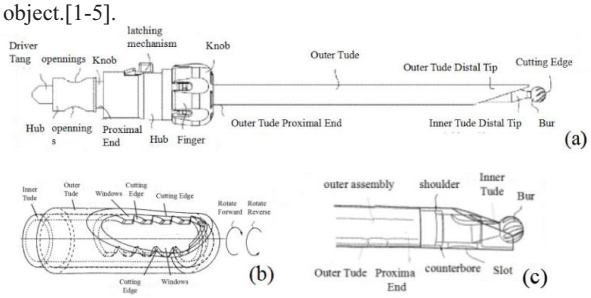

Fig.4 Arthroscopy cutting tool[6,7,8]

(a)Overall structure; (b) Shaver; (c) Bur

2.2. Type of arthroscopic cutting tool

There is a tremendous variety of arthroscopic cutting tool to choose from. According to the function of arthroscopic cutting tools, they can be divided into the following three groups. First, there are shaver that are designed to remove soft tissue such as synovium, fat pad, plicas and ligament remnants. Second there are shaver to trim denser soft tissues such as meniscus, articular cartilage or glenoid labrum. Third there are bur and other shaver for removing bone .

The soft-tissue shaver has two main type. One is a closed-ended synovial shaver, and the second an open-ended full-radius shaver. The closed-ended shaver has the advantage of being safest. However it can cause significant damage to