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Nontraditional Machining Process in Healthcare Applications

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ABSTRACT

Although continuous progress in technical advancement, the conventional machining process has became unsatisfactory in healthcare due to its disadvantages. This inadequacy has led researches to consider using the application of nontraditional machining that can machine extremely hard and brittle materials into complicated shapes in healthcare. Researches have proved that diverse NTM applications of Water Jet Machining (WJM), Ultrasonic Machining

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(USM), Laser Beam Machining (LBM), Wire Electrical Discharge Machining (WEDM) and Electrocautery are appropriated in manufacturing medical devices and implants for many different fields due to their several advantages. Tissue cutting operations are one of the fields where NTM technologies are widely used. In this review study, firstly, seven NTM technologies were investigated and represented with details to decide most suitable technologies for healthcare field. After this investigation, a literature study was conducted by focusing on WJM, LBM and Electrocautery device that are the most convenient using in tissue cutting operations in healthcare. For this review, 38 articles that have been studied after 2004 classified for the most popular 3 technology in this area, which are WJM, LBM and Electrocautery device.

Keywords: Nontraditional Machining Process, Water Jet Machining, Laser Beam Machining, Electrocautery, Healthcare

INTRODUCTION

Nowadays, all manufacturing companies run against global market. This situation leads them to produce new materials, to search for new products and production methods. Applications which provide to generate complex shapes with the required tolerance and surface roughness for advanced engineering materials are limited in traditional machining methods. Thus, nontraditional machining processes take the place of traditional machining processes in most area (Temuçin et al., 2014). In conventional processing methods, the material is removed in the form of sawdust on the workpiece thanks to help of a cutting tool. On the contrary, NTM processes make use of the more recent methods of mechanical, electrical, thermal, and chemical energy, or all, to gradually remove material from the workpiece by erosion. While physical tools are used in traditional methods, NTM processes do not require these tools, such as the use of laser light in Laser Jet Machining (Harničárová et al., 2013). Unlike traditional processing methods, tools used in NTM do not need to be harder than the working material and any contact is found between material and tool. On the contrary, there is direct mechanical contact between material and tool in traditional machining. This results in undesirable properties of the workpiece, such as mechanical and thermal stress.

NTM also successfully met with the need of ability to machine extremely hard material such as bones and brittle materials into complicated shapes in human body. With its features, the production of medical devices had significant technological improvement. Today, diverse NTM applications are appropriated in manufacturing medical devices and implants to be used in many different healthcare fields. Furthermore, there are continuous developments at applications of Water Jet Machining (WJM), Ultrasonic Machining (USM), Laser Beam Machining (LBM), Electrocautery and Wire Electrical Discharge Machining (WEDM) in the area of machining of medical equipment.

In this study, firstly, by looking at terms such as advantages, disadvantages, application area, working mechanism and related techniques, seven, NTM technologies are examined and showed with details to decide three most suitable technologies for healthcare field. In section 2, this information is presented by tabulating under the heading 2.1. Then, three technologies that are most convenient and recently most popular have been decided for tissue cutting in the field of healthcare. These technologies are WJM, LBM and Electrocautery devices, summaries of information about these devices are also collected under headings 2.2, 2.3 and 2.4. Later, in section 3, literature reviews of these three devices were carried out. Headings 3.1, 3.2 and 3.3 consist of compiling and classifying studies since 2004 for WJM, LBM and Electrocautery device, respectively. Finally, in discussion and conclusion part, analyzes were made about the study, deficiencies related to the subject in the study were observed and suggestions were made for future studies.

NONTRADITIONAL MACHINING PROCESS

General Information of 7 NTM Processes

Seven NTM technologies were investigated and represented with details to decide three most suitable technologies for healthcare area in terms of advantages, disadvantages, application area, working mechanism and related techniques. At table, the information was classified under the related headings for Electrochemical Machining (ECM), Ultrasonic Machining (USM), Water Jet Machining (WJM), Abrasive Water Jet Machining (AWJM), Abrasive Flow Machining (AFM), Laser Beam Machining (LBM) and Electrocautery device.

Table 1: General Information about NTM Processes

		Advantages	Disadvantages	Application Area	Working Mechanism	Related Techniques
NTM Process	**ECM**	No tool wear, no residual surface stress of workpiece, no thermal damages on workpiece structure, low surface roughness, requires low voltages, can machine difficult conductive materials, fast processing speed, convenient for mass production work, low labor requirements	Safety issues during machining process of hydrogen gas, complexity containing the electrolyte, workpiece must be electrically conductive, very high tooling and equipment costs, high power consumption	Complex cavities in high-strength materials, esp. in aerospace industry for mass production of turbine blades	A dc voltage (10-25 v) is applied across the gap between a pre-shaped cathode tool and an anode workpiece. The workpiece is dissolved by an electrochemical reaction to the shape of the tool.	EMM is the application of ECM on micro features ECDM process is a hybrid machining process that is combined of ECM and EDM to have better qualities especially on electrically non conducting materials ECJM applies electrolyte jet in order to solve workpiece material anodic. ECH is hybrid of ECM with conventional MH
	USM	No heat-influenced area, no residue tension on processed pieces, the high cycle fatigue strength of the processed piece, more productively processed fragile materials, rapidly processed complicated three-dimensional contours, it is a process without burr and distortion, snugly and easy to use equipment.	Material Removal Rate is low (about 3 mm3/s), higher strength consumption than traditional machining processes, deep holes are hard to be processed, limited movement of slurry.	Rigid and fragile workpieces to give shaped vehicles, ultrasonic frequency mechanical pulsation and to make holes and gaps with a corrosive slurry, rigid and fragile materials (both electrically conductive and non-conductive material) with a toughness greater than 40 HRC.	The master elements of ultrasonic machining are high power due to wave generator, magneto strictive transducer, tool holder and tool, it uses mechanical energy as its source, the power supply has a big role since it converts electrical signals from low frequency to high frequency, the signals transmitted from the transducer are converted into mechanical vibration.	RUM is a hybrid NTM process, which compounds material extraction mechanisms of corrosive grinding and ultrasonic machining
	WJM	No need for predrilled holes, no heat, no workpiece deflection (hence suitable for flexible materials), minimal burr, environmentally friendly, multidirectional cutting capacity, it is convenient for mass production work and its labor requirements are low.	Limited to material with naturally occurring small cracks or softer material, not suitable for mass production because of high maintenance requirements	Drilling, descaling, deburring, cutting of printed circuit boards and profile cutting of fiber-reinforced plastic aircraft structures, cutting and grinding of dental materials, cutting endoprostheses and bone, resection of soft tissues, cleaning skin graft, removing dead skin	Hydraulic Pump powered from electric motor Intensifier Accumulator High Pressure Tubing Jet Cutting Nozzle Catcher	AWJM Pure Waterjet Drilling PWJ

		Advantages	Disadvantages	Application Area	Working Mechanism	Related Techniques
NTM Process	**AWJM**	Any microstructural distortion is not formed with AWJM because workpiece is not exposed to high temperature. Good for cutting surface without any cutting tools. Complex shaped materials can be formed easily with the aid of pressured water and abrasives. AWJM has higher cutting speed than other cutting methods. AWJM is environmentally friendly process.	Disadvantage of AWJM is that this technique cannot be used for food, polymer and leather industries because abrasive water jet machine includes toxic abrasive parts.	AWJM is used to process difficult-to-machine materials (e.g. structure of polymer matrix composite materials includes reinforcement elements). AWJM is used for cutting composite materials, ceramics and stones, brittle materials like glass. AWJM is used aerospace, automotive, electronic, mining and metal industries frequently. For example, engine parts, titanium bodies of military aircrafts and car bumpers are produced with this machining method.	Cutting process is implied by a water jet that comprises abrasive particles. AWJM consists of high-pressured water, path of abrasive particles, mixing chamber, primary (orifice) and secondary (focusing tube) nozzles. Working principle of AWJM is mixture of water and abrasives under the high-pressure jet which provides high velocity to metals and alloys. Abrasive materials are speeded up by high pressure water. After that, this mixture is sent to surface of target material for cutting and processing by means of nozzle.	
	AFM	Compose of appropriate operation, low production cost, complex shape processing, higher brightening productivity, quick surface and edge finishing process, low amplitude swingings of the workpiece according to the self-composing elastic and plastic corrosive lustring vehicle.	A softer surface of work piece is not simply achieved, restriction in the lower proportions of material extraction.	To deburr, radius, polish, and extract reformed layer of the complicated geometries and rigid materials, Automotive, Aerospace, Medicine, Dies and Molds.	Abrasive Flow Processing operates through a holding apparatus under the pressure of an abrasive charged, viscoelastic compound or abrasive medium and with back and forth flow over the lustered, deburred and dispersed area, a surface finishing process is carried out by the flow of a paste-like abrasive fluid through the workpiece.	
	LBM	• High precision • Small heat-affected zone • Low level of noise • No need of special fixtures for the work piece • No need of expensive or replaceable tool • Low waste	The initial investment cost in laser production is high. The efficiency of the laser is low. As the eye and skin are in constant contact with light, it may pose a health hazard to users.	The LBM is mostly applicable in largescale production like shipbuilding, car manufacturing, aerospace companies, and electronics industries. Lastly, LBM can be particularly useful in the fabrication of unique non-conductive materials and in producing fine, precise and small parts.	It is main principle is to send a high energy laser beam so that it hits the surface of the material. After that the heat energy that the laser beam has gets transferred to the surface of material. In this way the machining of material takes place to the use of laser beam.	
	Electrocautery	Electrocautery cut open through the alternative current which causes the blood to clot without damaging adjacent tissues. Electrocautery generates incision more quickly. In operations using electrocautery, bleeding volume is low and opened wounds are small.it provides a clear field of vision during surgery.	Electrocautery may cause the formation of overheating, causing thermal damage. Therefore, electrocautery can sometimes lead to the formation of infectious wounds and cosmetically poor results.	Electrocautery is commonly used due to its advantages in brain surgery, dentistry, plastic surgery, gynecology, general surgery, orthopedic surgery, cardiovascular surgery, urology, cancer surgery. It is often used to reach benign and narrow space tumors.	Electrocautery produce energy in the range of 15-400 Watt with the help of a special conductor with high frequency electric current. It has become widespread in the surgical field with the use of electric current. The high frequency current produced by the electrocauters may be in the form of a full wave for cutting or a modulated wave for coagulation.	

Water Jet Machining in Healthcare

Due to the many advantages of waterjet technology, for instance; absence of thermal damage caused by temperature, absence of structural change of material, sharp and clean cut, controlled fluid pressure, absence of deformation, and reduction of blood loss, usage of water jet technology applications in healthcare drew attention of researchers. There are many search fields for water jet machining to be developed with many experiments (Nag et al., 2019; Tozan, 2011; Valíček et al., 2015). WJT can be used for resection of tissues, tumors, liver, and kidney, cleaning the traumatic wounds, releasing fat cells and saving nerves and blood vessels, removing dead skin as it is called hydro abrasive in dermatology, cholecystectomy surgery, neurosurgery, ophthalmology, oncology and dental applications.

Laser Beam Machining in Healthcare

Laser beam machining is one of the commonly used methods for tissue cutting and generating medical devices. Some wavelengths of laser beams provide both cutting and congelation of tissues efficiently. Also, Laser cutting ensures extremely thin, precise and clean cutting. For cutting and biopsy surgical instruments, unusual tipped needles, and flexible endoscopes, laser cutting provides higher precision, quality and speed than traditional cutting technique. LBM is applied to understand the changes induced in the bone in terms of temperature rise and thermal damage and to study bone healing under functional loading.

Electrocautery in Healthcare

Electrocautery is a method that is used for cutting tissue in surgeries. Electrocautery cut open through the alternative current which causes the blood to clot without damaging adjacent tissues. It is preferred to dissect muscle layers and fascia as well as to stop the bleeding. Electrocautery generates incision more quickly. In operations using electrocautery, bleeding volume is low and opened wounds are small. Electrocautery is one of the best devices to keep blood flow during surgery. Thus, it provides a clear field of vision during surgery. However, electrocautery may cause the formation of overheating, causing thermal damage. Therefore, electrocautery can sometimes lead to the formation of infectious wounds and cosmetically poor results, although it reduces the incision time and blood loss. Electrocautery is commonly used due to its advantages in brain surgery, dentistry, plastic surgery, gynecology, general surgery, orthopedic surgery, cardiovascular surgery, urology, cancer surgery. It is often used to reach benign and narrow space tumors. Electrocautery is a surgical instrument that can be used for cutting and clotting in tissue by producing energy in the range of 15-400 Watt with the help of a special conductor with high frequency electric current. It has become widespread in the surgical field with the use of electric current. The high frequency current produced by the electrocauteries may be in the form of a full wave for cutting or a modulated wave for coagulation.

LITERATURE REVIEW

With the modern technology growth and the needs of new advanced technologies in surgeries, researches of water jet application, laser beam machining and electrocautery in cutting soft tissue have been examined with more detailed factors to see if it contributes to improve the quality of the operations. Experiments over years proved the availability of these technologies in cutting soft tissue.

Literature Review on Water Jet Machining

(Hloch et al., 2011) searched the issue of identification of factors in relation to the surface topography of bone tissue and the surfaces evaluated with using the surface profile parameters in order to identify desired surface quality. With their results, this research can set up a basis for future abrasive waterjet cutting application in orthopedic surgeries.

(Steven den Dunnen et al., 2013) analyzed applicability of pure water jet drilling in articular bones of four kind of mammals. Minimum water pressure and minimum penetration pressure were aimed to determine and they found the minimum-threshold pressures according to the research. Also, whether the abrasives are necessary to penetrate the articular is examined. Research result proved machining holes by using waterjet technology without abrasives is feasible and it is observed that the pressure is not the only criteria for controlling the depth of the hole.

(Hloch et al., 2013) aimed this research to compare of continuous and ultrasonic pulsating water jet from the performance view during bone cement disintegration and also for the purpose of its profitable applications in orthopedic surgery. Results of this experiment indicated the pulsating water jet is a suitable technology for bone cement removal due to the lowest pressures while continuous water jet is not suitable cause of high pressure. Their future expectation is with the innovation of the recent surgical procedures with utilization of water jet, this technique can be solid foundation in the competitive market.

(S den Dunnen and Tuijthof, 2014) goaled to see the effectiveness of different water jet nozzle diameters on drilling bone tissue. They used Pearson's correlation tests for each diameter and the results were shown on IBM SPSS Statistics. Their result showed there was no correlation between size of the nozzle diameter and efficiency of water jet drilling in bone tissue. Nevertheless, waterjet diameter should be preferred according to specific requirements without changing the total volume of water for example for irrigation system a smaller nozzle is recommended or for critical surgery larger nozzle is advised.

For a first time, water jet cutting technique is applied by (Kraaij et al., 2015) to remove interface tissue between bone and the orthopedic implants in loose hip prostheses. Due to the lack of the information of water jet usage for interface tissue they studied the waterjet settings and examined the feasibility of this cutting process by using 132 interface tissue samples and results showed removing interface tissue in loosened hip can be applied by water jet technology.

A problem of heterogeneity of bone tissue causing variation in drilling depth was led (S den Dunnen et al., 2017) searching ways to improve the control over drilling depth. They compared CWJ with SWJ considering drilling depth and jet time. Their result confirmed using colliding water jets in bone tissue follows smaller variance, shallower drilling depth and a smaller influence of the jet time during drilling therefore it provides better depth control and safer water jet application.

(Hloch et al., 2019) focused on PLJ that consists saline solution for bone cement removal application and determine the minimal liquid pressure that is necessary for the removal procedure. Their study showed using saline solution caused the pressures of liquids to be significantly lower. Although, increasing pressure causes erosion on material surface and increases the removed material, the results showed there is no remarkable difference at lower pressure cause of the inertness of the fluids.

Literature Review on Laser Beam Machining

(Wallace et al., 2004) focused on the thermal effects during cutting bone and the lased bone surface profile in order to minimize tissue damages caused by laser cutting process. The results compared with conventional sawing and their records showed lased tissue's temperature is significantly low and lased surface is rougher than original bone. Despite to their results, they concerned that more studies about determination the level of laser pulse energy are needed.

(Iliescu et al., 2004) gives a method and apparatus which provides to machining bone with laser assisted without increasing temperature around the bone in surgical operations.

Method and apparatus were found as advantageous and successful because clean, consistent and monochromatic beam is provided to area to be processed chemically.

To provide steady adhesion for medical implants or fixating bone tissue, the effects of creating micro holes with laser on metal surface were investigated in the (Man et al., 2010). The number of holes per unit area has been observed to affect logarithmic joint adhesion strength. Moreover, different hole geometries are recommended for improved adhesion and bone tissue fixation.

(Cloutier et al., 2010) wanted to compare femtosecond laser and Er:YAG laser ablation with mechanical drilling in order to evaluate the bone healing process. Besides observing healing process, they analyzed whether the addition BMP-7 to the bone effects the laser ablation or not. Their experience showed that between femtosecond and mechanical drilling, femtosecond showed slightly delayed bone healing and between Er:YAG and mechanical drilling, their healing rate is similar to each other. Also, addition of BMP-7 is suggested to mechanical drilling or laser.

Also, (Allegrini et al., 2014) conducted to observe changes in implant surfaces and evaluate response of bone to treatment which are treated with laser. As a result, it was found that the roughness and oxide layer on the surfaces of laser-treated implants responded better to bone repair than implants with simply machined surfaces. On the laser-treated implant surfaces, new bone tissue is formed more rapidly and distinctly.

Hydroxyapatite (HAP) is the most widely accepted biomaterial for artificial substitutes of hips, knees, teeth, tendons and ligaments, and is the biomaterial required for surgical repair to repair bone fillings. Laser beam machining method can be proved to be suitable for efficient processing of the HAP because of its good absorption capacity. (Ranjan and Mishra, 2016) conducted in relation to this and the potential of LBM in the processing of HAP was investigated.

It has been desirable to develop a scaffold manufacture that mimics the structure and function of the extracellular matrix. The aim of (Rahmani-Monfard et al., 2016) is to form a newly developed, predefined three-dimensional polymethyl methacrylate (PMMA) scaffold produced by CO2 laser drilling technique. In this study, three-dimensional laser perforation of PMMA scaffold used for bone regeneration was observed. Three sets of samples with increasing porosity levels were produced.

In (Boyde, 2018), laser ablation method was evaluated in terms of problems arising from bone, joint and dental tissue where thin and intact parts were needed.

(Šugár et al., 2019) was about developing osseointegration of the titanium implants. In this study, laser beams with different energy levels were applied to machine Ti. As a result of this analyze, different pulse laser energies led to different surface quality of dental implants.

Literature Review on Electrocautery

(Du et al., 2010) wanted to assess the efficacy and safety of ECT as against MIT taking consideration to surgical time, blood loss, complications and time to recover with 501 participants. The results showed that these two compared groups were similar at surgical time but have differences between in blood loss. In conclusion microdebrider tonsillectomy is an efficient technique at reducing the time to of return to normal life.

(Roby et al., 2011) designed an electrocautery that conducts the temperature using a conduction path in order to reduce thermal damage and bleeding during surgery. As a result of this study, with this new study, researchers are expected to reduce these problems by using direct current instead of radio frequency and to achieve clotting temperature faster than the temperature provided by the current device.

Purpose of (Currie et al., 2012) study is to evaluate the outcomes of ultrasonic dissection and standard electrocautery after mastectomy for breast cancer and discuss these results to prove the better technology. The study results show that ultrasonic dissection and standard electrocautery have very similar outcomes specifically for postoperative drainage and seroma development, in the setting of mastectomy.

An automatic device for comparing the depth and quality of morphological changes caused by US and ME is developed by (Homayounfar et al., 2012) for this study. Thermal injury caused by US and ME results in qualitatively similar coagulation necrosis. Furthermore, the depth of necrosis is significantly bigger when ultrasonic scalpel is used comparable to ME. However, interaction between the dissection tool and the mode of excision was not found.

In another study, (He et al., 2012) compared harmonic focus with electrocautery to achieve safe surgery and the result is not different from other researches, reduction in operative time, blood loss, total drainage volume, days of stay, and visual analogue scale for harmonic focus while no significant differences in seroma, hematoma, and flap necrosis for both groups.

(Kleinhans et al., 2014) created a device with direct current from the body, which is a more effective and safer alternative to electrocautery, reducing blood loss and using a temperature that prevents electric shocks. Consequently, expectations are to reduce costs and increase safety, and these expectations have been confirmed by studies. Electrocautery reduces the time of surgery and hospital costs by decreasing observing time of the cardiologist. In addition, since it only uses current in etching, it eliminates the risk of leakage and eliminates the possibility of first and secondary burns.

Gingivectomy is a dental procedure in which a dentist or oral surgeon cuts a portion of the gums in the mouth. The use of laser and electrocautery in various aspects of gingivectomy operation has been investigated in (Kumar et al., 2015). It has been investigated whether any technique has advantages over the other to cut of gums in mouth. The parameters at the time of operation and postoperatively were evaluated as operation time, bleeding, tissue adhesion, postoperative pain and recovery. The results were statistically analyzed and compared. Both techniques showed equal yield and wound healing in the gingivectomy operation. The electrocautery or laser did not have an advantage over each other.

(Lee et al., 2017) hypothesized harmonic scalpel is reliable than electrocautery in terms of operative time, flap elevation time, drainage volume in DIEP breast reconstruction surgery. Data were analyzed at statistical software SAS after tests. According to results, harmonic scalpel was a better option for operating and flap elevation time while drainage volume and length of hospital stay were the same for both of the groups. Although this study is first to indicate the harmonic scalpel can be better than bipolar electrocautery during pedicle dissection in DIEP flap surgery, electrocautery is more common technique in surgical field.

(Verma et al., 2017) compared harmonic scalpel with conventional electrocautery technique in neck dissection. The result is the same as other studies such as diminution in blood loss and similar operative time, postop drain, postoperative hospital stay.

Electrocautery reduces cut-off time and blood loss superiorly to scalpel surgery. However, electrocautery causes infection of wound, worse cosmetic results, a bad healing process. Thus, (Ismail et al., 2017) analyzes and compares surgical incisions with scalpel and electrocautery. In conclusion of this study, advantage of electrocautery was found as electrocautery provides a quick healing process with less blood loss and less pain after surgery.

Also, this research cannot reach a difference statistically in terms of cosmetic, infection of wound. Thus, using electrocautery was considered a more advantageous method.

Frenulum is a soft mucosal tissue between gingival tissue and tongue, lip and cheek, which limits the movement of the tissues by connecting them together. This situation is treated by frenectomy operation using laser, scalpel or electrocautery. (Gandhi and Gandhi, 2017) contrast healing scores of patients after frenectomy operations between these three techniques. Three groups were generated and some parameters such as bleeding, pain, presence of infection, wound healing, satisfaction of patients were analyzed. Results showed that diode laser provides better operation and healing process for patients.

Electrocautery reduces the growth of scars and plays an important role in the treatment of patients with benign dyspnea. In (Bo et al., 2018), the efficacy and safety of combined electrocautery needle blade against balloon dilatation alone in the treatment of tracheal stenosis was evaluated. After treatment, symptoms such as shortness of breath immediately improved in all cases. The degree of stenosis of patients treated with electrocautery needle blade with balloon dilatation improved better after 3 months than those treated with balloon dilatation therapy alone. In conclusion, the use of electrocautery in combination with balloon dilatation provided a safer and more effective treatment.

(Ragulin et al., 2018) aimed to evaluate effectiveness pulmonary metastases after surgery with various techniques according to results and complications of surgery. Patients were divided to two groups. Electrocautery was used in one group and laser was used in the other group. Number of complications in the surgery using laser is less than surgery with electrocautery. As a conclusion, results were more advantageous for ND: Yag laser surgery.

Electrocautery and Harmonic Scalpel are currently widely used in patients with neck dissection for cost validation and doctor choices. Nevertheless, the use of Harmonic Scalpel over Electrocautery is a common standard in this field. (Agrawal et al., 2018) studied the blood loss in a patient with cancer has selective neck dissection using these devices. In the end, peroperative blood loss was importantly lower in the patient team using the Harmonic Scalpel device compared to the patient team using the Electrocautery device.

(Derriks et al., 2019) is an experimental study about the use of electrocautery during arthroscopy which can warm the intra-articular fluid and then damage the intra-articular and extra-articular tissue. Some new electrocautery devices can measure the out-fluid temperature and shut down before reaching a certain threshold. This study aims to analyze the current literature on temperature thresholds for tissue damage after exposure to heated fluid and to provide a recommendation for the maximum temperature of the intraarticular fluid to prevent tissue damage. Considering the studies and available literature, a temperature threshold of 43 ° C was proposed for intraarticular fluid during arthroscopic procedure to prevent tissue damage. It has been observed that higher temperatures can damage the surrounding internal and external joint tissues.

Due to the lack of randomized controlled trial to compare harmonic scalpel with electrocautery in recent studies, (Li et al., 2019) is indicated to analyze the differences of ultrasonic dissection and standard electrocautery. Outcomes of the study such as reduction in operating time, intraoperative blood loss, hospital stay, salivary fistula and transient facia during harmonic scalpel prove the superiority of harmonic scalpel over electrocautery.

The main cause of instrument failure in spine operations seen as cyclic loading, it spreads later then operation, which causes rod breakage. (Almansour et al., 2019) provides a biomechanical analysis of the fatigue life potential effect of the electrocautery device on spinal implants. In general, the aim is to examine the fatigue life of cobalt-chromium and titanium rod screws after machining with this device. As research result, titanium rods failed in the area where electrocautery was applied and fatigue life was reduced. Doctors should be careful around spinal implants, especially during revision.

DISCUSSIONS AND CONCLUSIONS

According to researched have done so far, it is undeniable fact that NTM is an advanced type of machining which are becoming quite important at modern engineering and its application areas are getting increased. One of these fields where NTM is preferred to healthcare where medical equipment requirements are difficult to meet with standards and carries significant importance. With the evaluation of NTM processes and specifically its 3 process' applications in healthcare, it is seen that there are continuous developments at different healthcare areas and at different countries. Moreover, literature reviews are evaluated according to these 3 technologies usage at tissue cutting operations in order to limit the research and analyze their applications in detail. The reviewed researches showed these processes are very promising and available for further developments.

Electrocautery is one of the NTM technology which is widespread in the surgical field and it has some disadvantages although taking into account other criteria such as low cost, easy applicability and being preferred in a wide variety of surgeries. Some areas where electrocautery is used are brain surgery, dentistry, plastic surgery, gynecology, general surgery, orthopedic surgery, cardiovascular surgery, urology, and cancer surgery. Laser Beam Machining is also one of the important process which has unique applications in surgical field and treatments due to its advantages at giving fast, clear and precise cut, not causing heat damage to the surrounding area while traditional cutting technique does not have these advantages. Commonly, it is used at cosmetic surgery, eye surgery, and hair removal. The last NTM process that is evaluated from only international literatures is Water Jet Machining. Studies proved that advances in water jet systems are facilitating their increased use in new medical ablation or cutting applications in many different fields such as cardiology, orthopedics, ophthalmology, dermatology, oncology and neurosurgery. Although WJM is used in dental operations, it is noticed that it has no sufficient applications in tissue cutting operations in Turkey.

The variety and importance of the NTM studies have carried out in order to capture the developments in the field of tissue cutting operation is clearly stated with the detailed literature study. It is striking that most studies about Electrocautery, LBM and WJM belong to European countries, India and America. It has been observed that the number of studies on the use of electrocautery and LBM in tissue cutting made in Turkey is behind European countries while the studies on WJM only existed in the field of dental in Turkey. To the best of our knowledge, with the detailed review of the literature, a study that compiling studies of WJM in the area of tissue cutting operations was not encountered in Turkey. This situation can be related with the research opportunities of NTM processes in Europe and other countries are established many years before than it is established in Turkey. This review study is expected to be a guide to all stakeholders in this field by removing the deficiency in the literature.

Consequently, there are many NTM processes and their usage areas in industry such as automotive, aerospace, electronics, and medical. The diversities of process get increased even at one specific field according to the need. Accordingly, there are various studies in the literature and the studies carried out are increasing day by day. With the awareness of medical sector is one of the most vital sectors around the world and the consideration of the developing technology, it was concluded that the studies of electrocautery, LBM and especially WJM are not sufficient at the national level so the studies on these subjects should be increased.

Ethical Approval: Since the article is a literature review, there is no violation of ethical rights, so an ethical approval does not require.

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