New Device for Controlled Resection of Nasopharyngeal Swellings

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Abstract: Presently otorhinolaringological surgeons face a problem of lacking of the control in adenoidectomy, which means excision of a swelling that are located between the nasal airway and the back of the throat (nasopharynx). That is why it's called blind operation in otorhinolaringology, leading to uncertain removal of the bad and good tissues. This research removes this uncertainty, eliminates a major problem, and risks during the surgery. This research introduces a new tool to enable the surgeon to view surgical area, to be able to control the certainty of the operation. This developed tool consists of three main parts; DC motor connected to blade, visualization sensor connected to a monitor and suction tube. The motor is connected to special shaped blade (rotational knife in a window) suits the volume and shape of the swelling, and also follows the international dimensions standards. This device enables the surgeon to see the target area and directing the blade towards the desired tissue to be removed, frees surgeon's hand used to carry the endoscope. Moreover, the device gets rid off the unseen region under the endoscope as it avoids the surgeon to use the nasal opening for the endoscope. The cut tissue is drawn via suction tube. The amount of removed tissue can be easily visualized online and perfectly controlled, which increases the safety factors for adjacent structures/tissues such as; The Eustachian tube (orifice) and pre-vertebral muscles. Hence, the adenoidectomy operation becomes more accurate. Theoretical model was made by calculating the tool parts which was obtained through the existent experimental work, to get the optimum blade velocity for removing the target tissue. For a better visualization and precise control a built-in suction orifice added to the tool to clean the bloody field during the operation. A small lamp is located backward of visualization sensor to allow perfect vision during the operation. Also aggregation cavity was added to the new tool which is used to aggregate fluid during adenoidectomy. As a result, the adenoidectomy performance becomes faster and safer than the available traditional devices, besides freeing the surgeon's hand used to carry the endoscope.

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1. Introduction

Adenoid removal surgery is to take out the adenoid glands, which are located between the nasal airway and the back of the throat (nasopharynx).

This procedure is also called an adenoidectomy. It is frequently done at the same time as a tonsillectomy [1, 2]. While the patient is under general anesthesia, the ENT surgeon inserts a small instrument into the mouth to prop it open. The adenoid tissue can be removed with an instrument such as a curette or a microdebrider. Some surgeons may cauterize the adenoids instead of removing the tissue.

Bleeding is controlled with packing and cauterization [3, 4, 5]. The adenoid is a mass of lymphoid tissue in the roof of the nasopharynx, located just inferior to the sphenoid sinus and anterior to the basi-occiput. Laterally, the adenoids blend with the lymphoid tissue of the fossa of Rosenmuller near the opening of the Eustachian tube. The adenoids are present in all infants and children, and start to regress just before puberty. They are usually absent in adults [6, 7]. Large adenoids produce nasal obstruction, mouth breathing, nasal voice, snoring and restless sleep. Chronic mouth breathing during the age when the facial bones are changing toward the adult configuration often produces a high arched palate, the pinching in of the nose and a shortened upper lip, with a staring expression of the eyes. The face becomes slightly elongated and the upper teeth may be prominent [8, 9]. These changes are called adenoid faces [10]. In addition, hypertrophy of the adenoids may also produce obstruction of the Eustachian tubes and contribute to the formation of middle ear effusions.

Adenoidectomy is a common procedure for treating pediatric ear, nose, and throat patients. Nowadays, it is used to treat Enlarged adenoids that have not responded to conservative treatments which are indicated in obstructive sleep apnea, recurrent serious otitis media, and resistant rhino sinusitis [11, 12].Typically, the adenoids might not have been visualized during clinical examination in ENT clinics because the pediatric patient may not cooperate during a mirror or endoscopic examination [13]. Furthermore, lateral radiographs of adenoids are not routinely investigated before an adenoidectomy. In many cases, the size of the adenoids is assessed by a transoral finger palpation or a mirror examination following the anterior retraction of soft palate by a nasal catheter [14, 15]. Most surgical procedures performed today with classic tool until now [8]. The surgeon cannot view the desired tissue well so that the surgical process becomes difficult and more complex [2, 8].

Partial adenoidectomy with the microdebrider was performed with the Xomed Adenoid microresector blade at 3000 rpm in oscillate mode without Irrigation. After tissue removal via either technique, electrocautery was used for hemostasis [14] . This technique involves the removal of the superior 50% to 80% of the adenoid pad, which leaves an inferior tissue remnant undisturbed to ensure adequate velopharyngeal closure [10] .We have shown that partial adenoidectomy with the microdebrider is faster remove speed, but there is no tissue remove matching with microdebrider speed, and so may be injury to adjacent structures [10,13,15] . Also adenoidectomy with endoscopy is particularly useful for pediatric age group patients who have small oral cavities. The assessment and excision of the adenoids in these cases are often difficult. Because the size assessment of the adenoids by conventional palpation and mirror examination is challenging, and the placement of the adenoid curette guided by the indirect mirror is difficult. Moreover, it uses the classic adenoidectomy curette, so the operator uses his both hands during the operation, as a result difficult management and decreased accuracy of the procedure [3,4,7,8]. One of the main problems of this operation is that the surgeon cannot view the desired tissue well, so that the surgical process becomes difficult and more complex.

This new tool designed to perform good removing tissue by obtaining the desired velocity of blade and motor by choosing the best result from our work. and also, This tool supplied with control unit that allows a perfect control during adenoidectomy, Safety divider to prevent remove the undesired tissue during adenoidectomy operation , and aggregation cavity and etc. as shown tool design, the tool presented in this paper solved this problem, where adenoidectomy operation could be performed in a safe and accurate way due to the added facility of proper visualization of the nasopharynx which enables the surgeon to completely remove adenoids. In addition, Adenoidectomy with this presented tool is faster than adenoidectomy with curettes or a microdebrider, because of the perfect matching between rotational blade and bad tissue (adenoid) shape and size during tissue removal.

2. Tool design

This paper tool which is faster and more accurate for adenoidectomy is designed to have important advantages over the conventional adenoidectomy like improvements in curette or a microdebrider accuracy and shorter duration of operation.

This technique involves the removal up to 100% - depending on the surgeon's own skills - of the superior adenoid pad, which leaves an inferior tissue remnant undisturbed to ensure adequate velopharyngeal closure.

This tool is equipped with visualization sensor which is connected to a monitor allowing perfect vision during the operation. Consequently enabling the surgeon to view surgery area and becomes able to fully control the certainty of the operation.

3. Design

The design considers the four principal factors to control this research tool performance; the distance of blade movement, accuracy of cutting tissue, safety of surrounding tissue and time of tissue removal. According to the international standards the distance of cutting blade is chosen to match the available classic tool (curettes) which is 26 mm. This distance also matches the optimum speed and time of cutting unwanted tissues. Experienced surgeons approved that the slower cutting velocity, the safer operation. But on the other hand, the increase of velocity reduces operation time which is appreciated by surgeons and patients. A comparison between those two crucial factors is considered in this paper tool design. Hence the blade velocity V could be related to the tissue under removal size and elasticity as given $V=Wr = 2\pi Nr/60$ where N is the DC motor speed, W is the angular velocity and r is the radius of gearbox. The two gears having the parameters r1 and N1 for the first and r2 and N2 for the second. Considering linear velocity $v = x/t$ where x distance of blade movement and t time of tissue removal. Since gear B and blade are tightly contacted, they rotate with the same velocity Therefore, $v2=x2/t$. For x equal the standard distance 26 mm then; $v2 =26/t$. From results shown in table 1 page 6 and according to the experienced surgeon's recommendations we select operation time 60 sec and its corresponding velocity 0.43 mm/sec. Hence according to the equation $v2 = 2\Pi N2r2/60$, N2 = 50. The speed ratio of the gears $I = N1/N2$ = the speed ratio, which is selected as 2:1 therefore N1 = 100 r.p.m. where N1= 2N2. The diameters of two gears D1 and D2 respectively, are related to each other with the equation: $\Pi D1N1= \Pi D2N2$ OR $1/N2=D2/D1$. So we can get $D1 = N2\ D2 /N1 =50 *10/100 =5$ mm and r1 =2.5 mm. Finally the blade velocity v could be figured out as $v = 2\Pi N1r1/60=2\Pi*100*2.5/60=26.16$mm/s.

This obtained velocity would be considered the best match between movement and adenoid tissue. This velocity support higher cutting torque for the tool to ensure better safety.

4. The tool

The tool as shown in figure (1) consists of three main parts, DC motor connected with blade, visualization sensor connected to a monitor and suction tube connected to external suction device.

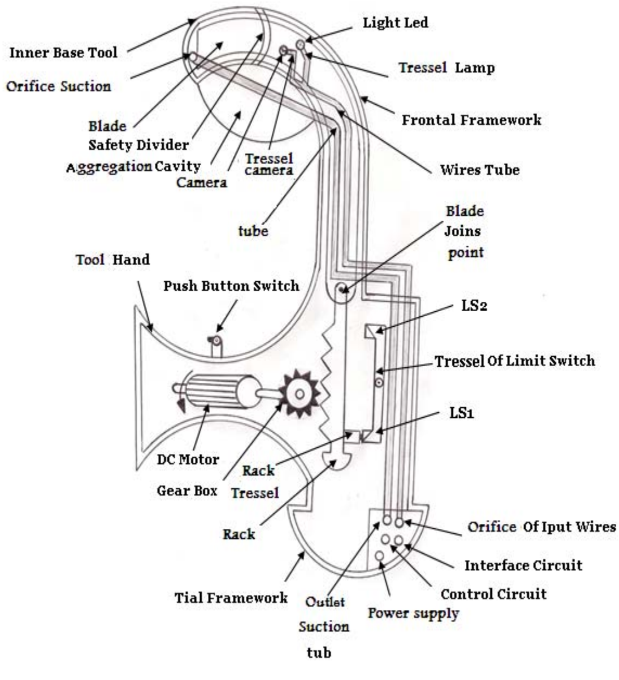

Fig. 1. Tool Construction.

The tool could be summarized as follows:
DC motor: permanent magnet type, with rated load speed 100 r.p.m, and rated load current 300 mA. Two limit switches are used to control the speed by connection gear box with motor shuft.
Gear box: located between the DC motor shaft and rack to control the speed of motor, and the cutting torque. Also matches the blade motion and motor speed.
Rack: located between gearbox and blade to transfer rotational motion of gear box into linear motion of blade. The rack is a rectangular prism with gear teeth machined along one side, could be considered a gear wheel with an infinite pitch circle radius.
Rack tressel (Rack arm contact): metal contact plate located on the rack that connect limit switches and the rack. The rack motion could be controlled by metal plate (Rack arm contact) connected to limit switches.
Blade: stainless steel metal anti-corrosion. It is connected with rack by bolt. Hence, start and stop motion of blade depend on the connection of rack arm contact with limit switch.
Limit switches: this new tool consists of two limit switches to perform perfect control during operation. First limit switch, It is normally closed (N.C) that is located towards the rack, the reverse direction is stopped when limit switch LS1is moved from its normal position, the normally closed contact opens and the drops out coil L. Second limit switch, it is has two sets of contact, one normally open (N.O) and the other normally closed (N.C), that is located towards the rack; it controls the direction of blade. Also Pushbuttons are used to initiate the motion control of the motor with second (N.C) limit switches so that blade then shaves the desired tissue. The auxiliary contact of the forward starter is connected in parallel with the pushbutton contact to maintain the circuit during the running of the motor in the forward direction. And terminate the forward motion control of the motor when rack arm contact connected with terminal second limit switch the (N.C) and (N.O) at the same time the motor reverses direction so blade motion direction is reversed after removing process.
The normally closed contact of limit switch LS2 acts as the stop for forward controller, and the normally open contact of limit switch LS2 acts as the start contact for the reverse direction .we can use Tressel (metal plate) to fixation and carry of limit switches.
Inner base tool (inner framework): It is the interior base tool that is a small cylindrical form which the surgeon directs towards the desired tissue.
Suction orifice: It is a small hole in the base tool beside the internal cavity; it is used to clear the bloody field during the operation by Suction tube which is a metal tube that connects suction orifice with external suction device, and it is made of stainless steel metal to overcome corrosion metal problem. We can clear bloody field from removed swelling through suction tube without insertion external suction tube so that the surgeon can be easy control during the operation because we make contraction of the number surgical tools in bloody field.
Safety divider/traverse: It is safe casement metal cylindrical form that is located on sides of blade to prevent remove the undesired tissue during removing desired (adenoids) tissue.
Aggregation cavity: Used to aggregation results adenoidectomy operation to clear the bloody field.
Light led: It is dc small lamp used to light the internal operation location, it is located backward of camera that allows perfect vision during the operation. Also we can use Tressel lamp to fixation of lamp above safety divider/traverse on frontal framework. We can obtain maximum light forward camera when angle between tressel lamp and tressel camera equals to 110 degree to get a perfect vision during the operation.
Lamp casing with glass is used to protect it from internal fluid during the operation.
Camera: Small camera is used to transfer internal picture of operation into external monitor screen, it enables the surgeon to view operation location during adenoidectomy operation. The type of camera is cmos sensor CCTV video camera with self interface circuit. Also Tressel of camera is used to fix the camera on safety divider/traverse on frontal framework and it must be perpendicular on location of operation to obtain perfect vision. Camera is cased in closed glass tube for patient safety and for isolating the camera from internal fluid during the operation.
Wires tube: It is a metal tube used to carry internal wires into camera and lamp. This tube must be perfect electrical isolation to protect the patient from electrical risks. And there is a small hole (Orifice of input wires) in the frontal framework used to insert wires into camera sensor and lamp.
Interface circuit: It is a connection point between internal camera and LCD screen
Control circuit: A reciprocating motion tool process that uses two limit switches to provide control of the motor. Each limit switch (ls1 and ls2) has two sets of contact, one normally open and the other normally closed. The operation of the circuit can be summarized as following: the start and stop pushbuttons are used to initiate and terminate the motion control of the motor by limit switches.
_using the control relay and its start and stop buttons also provides low-voltage protection.
_reversal of the direction of the rotation of the motor is provided by the action of the limit switches. The pushbuttons provide a means of starting the motor in forward direction. When limit switch (LS2) is moved from its normally position, drops out coil R and the normally open contact closed. The reverse action is performed by normally open contact of limit switch (LS2), the reverse direction is stopped when limit switch (LS1) is moved from its normal position, the normally closed contact opens and the drops out coil L.

5. Basic tool Operation

The tool shape and size are kept as close as possible to the classic tool. The surgeon will use this paper tool similar to the classic one. Only one button is to be pressed to turn on the motor to start the automatic cut of the tissue under the blade, directs the tool towards the desired tissue, then presses on pushbutton and second limit switch

N.C terminal point is connected so that the motor is forward direction(R) and the auxiliary contact of the forward starter is connected in parallel with the pushbutton contact to maintain the circuit during the running of the motor in the forward direction so that the rotating blade then shaves the desired (adenoids) tissue. When rack arm contact connect with terminal second limit switch the N.C and connect with N.O at the same time so that the motor reverse direction (L) so blade motion direction is reversed after removing process. When Rack arm contact connect with terminal first limit switch N.C the motor is stopped.

6. Tool results

From our mathematical model the following values of the velocity versus times is tabulated in table 1.

Table 1: relation between the blade velocity (v) and time of tissue removal (t) at distance of blade movement x=26mm

Time in sec	1	10	30	45	60	70	90
V mm/sec	26	2.6	0.86	0.57	0.43	0.37	0.29

From above data we can obtain the more accuracy of the bad tissue removing at the operation time is 60 sec with blade velocity 0.43 mm/sec. Our results are in accordance with those demonstrating a time advantage of this tool in complete adenoidectomy operation was performed with full control over tissue removal, safer and faster than that with curettes, because at this speed there is a perfect matching between blade velocity and adenoid tissue during operation, also the cutting torque of blade is high so that due to greater control over tissue removal.

Results of this study show that research tool has a number of advantages. Visualization sensor allows easy size assessment of the adenoid and improves the accuracy of the adenoidectomy via conventional curette. Also control unit that allows a perfect control during operation. All current problems can be solved by the use of research tool, which allows accurate placement of the adenoid curette at the superior border of the adenoids. This positioning allows the complete removal of the main bulk of the adenoid without the need for nasal punch forceps, Nasal endoscopy and a microdebrider. In all cases, the developed tool is sufficient to remove the main piece of the adenoids in one attempt. In contrast, the adenoid tissue is removed in multiple small pieces in the classic blind curette adenoidectomy method (according to ENT surgeon's experience). In ENT surgeon's experience, there is only a minimal increase in the operating time. Although further studies might be required to confirm the above advantages, we believe this tool is a good alternative method for adenoidectomy.

7. Conclusion

In this paper, developed tool is to overcome the current problems of recent procedures (diathermy, classic tool and endoscopic adenoidectomy) during resection of nasopharyngeal swellings especially during adenoidectomy as follows:

1- A small camera fixed perpendicular on location of operation to obtain perfect vision and control during operation (Otorhinolarngology call blind operation).

2- Safety divider to prevent faulty removal of adjacent tissue structures, like the vertebral muscles , and the precious spinal cord. And also the Eustachian tube which if injured or blocked can lead to repeated middle ear effusion.

3- Control unit contains a Dc motor connected to blade through rack and gearbox to control its speed.

4- The optimum motor and blade velocity were set up according to expert’s recommendations and our practical results.

5- In addition, no need for endoscope to view the operation field and also freeing the surgeon’s hand used to handle the endoscope.

To summarize tool advantages; Short duration of the operation, Perfect control and more accurate surgery, complete removal of the adenoids, no injury to adjacent structures, less chance of hemorrhage .

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