

# Development of Cervical Massage Instrument imitating Manipulation

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**Abstract:** In order to meet the action effect of pushing, kneading, squeezing, pressing and rolling of nerve root type cervical spondylosis, a new type of cervical massage chair imitating manipulation treatment is developed, which adopts the structural scheme of the combination of massage handwheel and eccentric wheel. Based on NX software, the structure of each part of the cervical massage chair is designed, the virtual prototype is designed, and the finite element analysis of the transmission spindle is carried out. The results show that the structure design is reasonable, the simulation action meets the contra direction synchronous 8-shaped curve track designed by massage handwheel, and the assembly structure is reasonable without interference. Using 3D printing technology, a prototype model was made, which laid a foundation for the follow-up biomechanical analysis and clinical application.

## 1 Introduction

Computer incidence rate of cervical spondylotic radicular spondylotic radicular disease is a cervical degenerative disease, which is mainly caused by the degeneration and protrusion of cervical intervertebral disc. It causes a series of clinical symptoms <sup>[1]</sup>, which is caused by secondary changes in the surrounding tissues and structures. Mobile phone is widely distributed among all kinds of people. The incidence rate is 2.4-12%. Trend<sup>[2]</sup>. The treatment of cervical spondylotic radiculopathy mainly consists of surgical treatment and non-surgical treatment. Surgical treatment has a certain risk, and the cost of treatment is high. At present, the proportion of clinical non-surgical treatment is more than 90% <sup>[3]</sup>. The non-surgical treatment methods mainly include manual therapy and medical device assisted rehabilitation therapy. In clinical practice, manual massage and massage therapy, cervical traction therapy, drug therapy, warm compress, infrared, electric pulse, ultrasound therapy, etc. are often used. One or two to three methods can also be selected according to different situations, and implemented at the same time <sup>[4]</sup>. The research shows that the clinical application of rotary lifting technique (push, knead, squeeze, press, roll on the focus of cervical vertebra, pull up, lower bend reduction, back shock and other actions) has a significant effect on the treatment of nerve root type cervical spondylosis. According to the physiological and pathological characteristics of cervical vertebra, traction of cervical vertebra according to the periodic loading and unloading law can achieve a better treatment effect <sup>[5]</sup>.

Li Weimin et al.<sup>[6]</sup> showed that traction treatment can

promote the regression of tissue edema and inflammation, increase the intervertebral space and foramen, reduce the compression of nerve root, restore the normal sequence and relationship between cervical vertebrae, and improve the blood supply of vertebral artery and the symptoms of spinal cord compression. In the process of traction, the weight, angle and time of traction are three important factors that determine the traction effect. Jiang Ying<sup>[7]</sup> shows that the best traction force is about 15% - 20% of human body weight. Li Yong et al.<sup>[8]</sup> measured the force on the cervical spine under different traction angles by the traction angle controller, and concluded that the axial effect of cervical traction on the intervertebral disc was the largest when it was in the neutral position, and the force was concentrated on the posterior edge of the vertebral body when it was in the forward flexion position, and transferred to the posterior facet joint when it was in the backward extension position. No matter which way of traction is adopted, its purpose is to make the maximum stress produced by traction effectively act on the lesion, so as to achieve the curative effect. Biomechanical study shows that the position of the maximum stress is related to the angle of traction. When the traction angle is small, the position of the maximum stress is close to the upper segment of the cervical spine; with the increase of the traction angle, the position of the maximum stress gradually moves down<sup>[9]</sup>. The results show that the best temperature is 20-30°C, followed by 15 °C. Therefore, traction with different angles can improve the curative effect. Generally, a certain rule must be followed in clinical practice, that is, when the traction force is large, the traction time is slightly shorter, generally 5-15 min, otherwise, it is slightly longer,

generally 20-30 min [10].

At present, the clinical and family use of cervical rehabilitation treatment equipment mainly includes two categories of cervical traction device: mechanical type and air bag compression type. The four head suspension type cervical traction bed (as shown in Figure 1) can adjust the traction time, traction force and traction angle according to the specific condition, effectively achieving the traction effect, but it has the disadvantages of single function, bulky volume and expensive price, which is not suitable for family use. The domestic suspension type traction device mainly includes the door hanging type (as shown in Fig. 2) and the long head type (as shown in Fig. 3), which is convenient to carry and cheap. Among them,



**Figure 1.** Mechanical traction



**Figure 2.** Door tractor



**Figure 3.** Long head tractor



**Figure 4.** Automatic cervical traction device

The air bag pressurized traction device is mainly used for home treatment. The patient can inflate by himself, control the traction force, and carry conveniently. However, the air bag rises in parallel, the force on the pillow and the lower neck is uneven, and the head is prone to recline. At the same time, the air bag expands to the inside and outside, and the inner diameter shrinks to make the neck suffer from centripetal compression, causing discomfort.

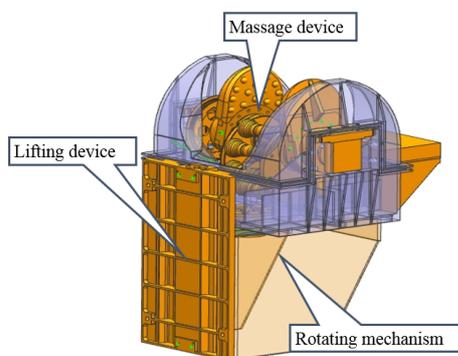
The ultimate goal of rehabilitation treatment of cervical spondylosis is to eliminate symptoms and signs, try to restore normal curvature, physiological function and working ability of cervical spine, but it cannot eliminate pathological changes such as degeneration of cervical intervertebral disc and hyperosteo-geny of cervical spine. At present, the development trend of cervical vertebra treatment equipment is as follows: it

the long head can also realize traction treatment in any position. However, it has been reported that the long-term treatment of four headband suspension traction can produce complications such as submaxillary neck syndrome. In view of this problem, there is a full-automatic cervical traction device (as shown in Figure 4). The mechanical analysis shows that the actual traction force of the improved traction device on the vertebral body adapts to the change of cervical curvature, maintains the physiological curvature of the cervical spine, and the traction force on each vertebral body at the same time. In the process of force transfer, the dispersion is reduced, which is better than suspension traction [11].

can deeply treat the cervical vertebra disease in many aspects, track and evaluate the change and treatment of the user's condition, which is convenient for the family use and the doctor's timely understanding of the condition. At present, the clinical and family used cervical vertebra rehabilitation treatment equipment can not meet the above requirements at the same time. From the perspective of biomechanics, this project will develop a new type of imitative manipulation therapy instrument. The ultimate goal is to develop a new type of imitative manipulation therapy instrument with high automation, which can meet the needs of clinical use and family health care.

## 2 The structure and working principle of cervical vertebra therapeutic apparatus

The design idea of multifunctional cervical vertebra treatment instrument is to imitate the action principle of manual massage. It can push, knead, squeeze, press, bend up and pull, bend down and reposition, swing left and right for the treatment of cervical vertebra disease at one time. The technical action of the instrument meets the requirements of manual effect. It can be used for clinical treatment or as a family physical therapy instrument, greatly improving the treatment effect of cervical vertebra disease Shorten the cure time. The structure is composed of three parts: transmission device, swing device and lifting device. The transmission device and the swing rotating device are successively connected and installed on the lifting device, and the structure is shown in Fig. 5. PLC is used in the control system, with high degree of automation, accurate and reliable action positioning and simple operation.



**Figure 5.** Main structure of multifunctional cervical vertebra therapeutic apparatus

**Working principle:** when the eccentric stent is in the initial state, the patient's cervical spine enters the specified position. After the machine is turned on, the decomposition action of massage hand wheel: to realize the forward push and backward pull, opening and closing extrusion, and the action is the movement track action of 8-shaped curve. Their continuous rotation realizes the manual massage of pushing, kneading, squeezing and pressing. When the eccentric support is turned from zero to 90 degrees anticlockwise, the head is lifted by the roller on the eccentric support. At this time, the cervical vertebra is pushed forward by the roller that rises one by one to achieve the effect of forming a circular force at the pushing point. Therefore, the stretching effect on the stubborn vertebra is produced. At the same time, the opposite hand wheel is pressed to move forward and backward to both sides of the cervical vertebra synchronously, spinning and pressing The curvilinear operation of the word track realizes the standard action of manual massage, and the therapeutic effect of pushing, kneading and squeezing. When the eccentric support is turned to more than 90 degrees anticlockwise, the opposite hand wheel at this time will start to reduce the pressure and operate separately for the pushing and rubbing and squeezing actions on both sides of the

human cervical vertebra. At this time, the left and right swings of the rotating base are in the left and right positions. The current movements play the mechanical actions required for the treatment of cervical vertebra joint stretching, pushing and kneading, forward bending and left and right bending. When the eccentric support turns to the limit of 180 degrees anticlockwise, the human head is lifted to the limit by the roller on the eccentric support. At this time, the cervical vertebra is pushed forward to the peak by the roller that rises one by one, realizing the limit effect of the circular force of the pushing point, so the whole bone section is stretched and bent forward for the stubborn vertebra section. At this time, the opposite hand wheel is used to separate the two sides of the human cervical vertebra by pushing, kneading and pressing. At this time, the left and right swing of the rotating base is still in the middle position. The current action is the mechanical action required for the dip therapy of stretching, pushing, kneading and pressing, forward bending and left and right bending of the male neck joint. When the eccentric stent rotates 270 degrees anticlockwise, the head is raised to the limit by the roller on the eccentric stent and quickly lowered to the pillow pad. At this time, the cervical vertebra section reaches the effect of backward bending and axial compression on the cervical vertebra section. At this time, the massage hand wheel begins to push, knead and squeeze the two sides of the human cervical region.

## 3 Design of main structural parts

Table 1 depicts the main technical parameters of the cervical vertebra therapeutic apparatus.

**Table 1.** Design parameters of cervical vertebra therapeutic apparatus

Neck diameter range	Massage frequency	Massage pressure	Massage angle	Rocking angle
80~140mm	30~60 f/min	2.5~5kg	0~12 °C	0~30 °C

### 3.1 Design of massage mechanism

The massage mechanisms is composed of spline main shaft, massage hand wheel, eccentric frame and fixed device, and adopts coaxial structure, as shown in Figure 6.

The power loss in the working process of the massage device includes the friction force in the massage process of the hand wheel, the supporting force in the rising process of the roller and the power consumed in the rotating process of the shaft. The calculation formula is as follows:

Power consumption of massage hand wheel:

$$P_1 = \frac{T_1 \cdot N}{9550} = \frac{f \cdot R \cdot N}{9550} = \frac{\frac{mg}{\cos 12^\circ} \cdot R_1 N}{9550} = 30.7 \text{ W} \quad (1)$$

Power consumption during roller rising:

$$P_2 = \frac{T_2 \cdot N}{9550} = \frac{mg \cdot R \cdot N}{9550} = 59 \text{ W} \quad (2)$$

Power consumption during shaft rotation:

$$P_3 = \frac{T_3 \cdot N}{9550} = \frac{mg \cdot R_2}{9550} = 7.5 \text{ W} \quad (3)$$

Total torque:

$$T_{\text{总}} = T_f + T_1 + T_2 = 15.5 \text{ N} \cdot \text{m} \quad (4)$$

Total power:

$$P_{\text{总}} = (P_1 + P_2 + P_3) / \eta \approx 145 \text{ W} \quad (5)$$

$m$ -cervical spine quality;  $R_1$ -radius of massage hand wheel;  $R_2$ -radius of shaft;

$N$ -massage handwheel speed;  $T$ -torque;  $\eta$ -total efficiency;

Spline main shaft is the main transmission component. NX Nastran simulation module is used for the finite element analysis, as shown in Figure 7. The analysis results show that the overall spline shaft structure of 45

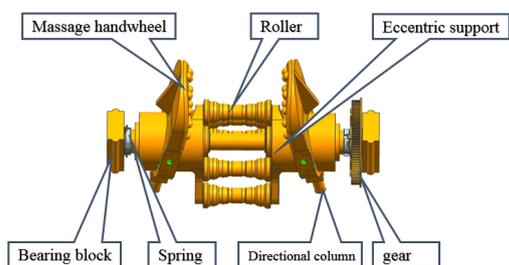


Figure 6. Massage mechanism model

steel meets the transmission strength requirements of the cervical massage instrument.

### 3.2 Design of lifting mechanism and swinging device

The lifting mechanism uses the lead screw as the driving part, pushing the nut to drive the slider bracket to complete up and down movement, and the dovetail guide rail on the bracket plays a guiding role, as shown in Figure 8. The shaft sleeve of the swinging device is fastened with the sliding block plane by bolts, and driven by the motor connected with the gear to drive the shaft sleeve on the sliding block bracket to rotate back and forth, so as to realize the swinging movement of the shell of the massage mechanism, as shown in Fig. 9.

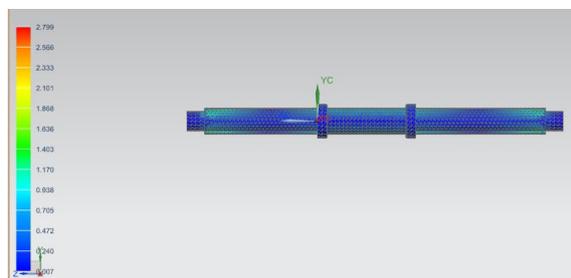


Figure 7. Working state stress diagram

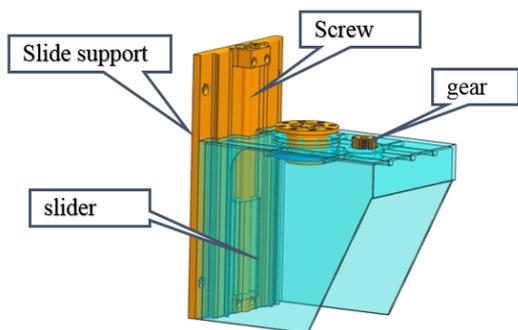


Figure 8. Model drawing of lifting device

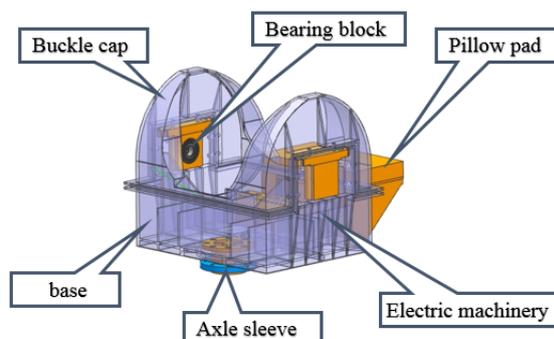


Figure 9. Model diagram of swing device

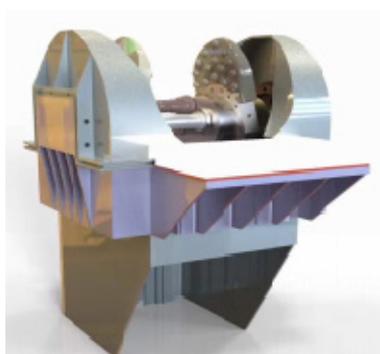


Figure 10. Product model rendering



Figure 11. 3D printing prototype drawing

## 4 Prototype production

According to the requirements of various movements of the current clinical manipulation treatment, the multi-functional cervical vertebra treatment instrument structure designed can realize the movement of pushing, kneading, squeezing, pressing, rolling, up bending and pulling, down bending and reduction, and back shaking on the focus area, and can also be used with different forms of bed at home. The virtual prototype design is completed, the structure is reasonable, the parts match well and there is no interference. The motion simulation action is reasonable, the eccentric hand wheel conforms to the 8-shaped motion track, the rotation angle of the eccentric wheel and the massage hand wheel conforms to the design requirements, and the rendering effect is shown in Figure 10. The prototype model was made by 3D printing technology, which laid a foundation for the biomechanical analysis of cervical massage and the collection of clinical experimental data.

## 5 Conclusion

The development of cervical massage instrument provides a new idea and direction for the treatment of cervical spondylosis. It has obvious advantages in the treatment and prevention of nerve root type cervical spondylosis. It can effectively alleviate the single function of the current cervical massage instrument and effectively reduce the impact of cervical spondylosis on human life. It is the key equipment for the prevention and treatment of cervical spondylosis. Cervical massage instrument can scientifically, economically and safely treat and prevent the patients with cervical health problems by imitating manipulation, which has great practical application and promotion value.

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