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Medical power supply equipment using piezoelectric composite material in cochlear implant

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Abstract

Based on lead zirconate titanate (PZT) with good adaptability and high performance, we collect the vibration energy generated by human face, Based on lead zirconate titanate (PZT) with good adaptability and high performance, we collect the vibration energy generated by human face, and collect the EMG signals of different muscles in normal face when chewing, and select masseter muscle as the main source of vibration energy collection . In order to better collect the vibration energy, we choose to thin the material and slice it, and sew it around masseter muscle after assembly to realize The self-power supply of cochlear implant.

Keywords

Lead zirconate titanate; EMG signal; Piezoelectric composite material; Vibration energy collection equipment.

1. Introduction

With the current continuous development of integrated circuit technology and biomedicine, the development direction of medical devices has been clearly distinguished. On the one hand, the shortage of in vitro devices is supplemented by the development of implantable medical electronic devices research. The industry has made remarkable achievements in the last nearly forty years. From implantable pacemakers and implantable atrial defibrillators to implantable cochlear implants used for the treatment of disabling conditions such as moderate and severe deafness, which have brought great benefits to deaf patients. There are close to 000more than 90,000 people with hearing disabilities in China and 200 .5million people with moderate hearing impairment worldwide, and the age-appropriate surgery can approach 90%, but there are many people who do not choose surgery mostly because of the risks of secondary surgery and the cost of expensive surgery. If the implantable power supply technology is further researched and developed to avoid the risk of secondary surgery and to surgically suture the energy collector to the temporal muscle of the face without affecting normal life, this will solve the power supply problem for implantable medical electronic devices.

Piezoelectric materials are a class of functional materials for the interconversion of mechanical and electrical energy. They include inorganic piezoelectric materials and composite piezoelectric materials. In order to implant reasonably into the body and not cause damage to the body muscle tissue, the human adaptability of the material is to be emphasized. The piezoelectric material we chose is pbbased-lead zircon-nate titanate (PZT), which is combined with organic piezoelectric polymer using etching technique and finally designed with flexible and malleable energy harvesting device (). In order to adapt to the most flexible muscle groups of the human face, the new piezoelectric device with its outstanding ductility and adaptability creates the conditions for it. The new piezoelectric device can be implanted in the human face as an implantable device to collect the kinetic energy generated by the human facial muscles for the following purposes: 1. to generate a highly stable and commercial grade electrical energy signal and store it in a battery for power supply; 2. to analyze the collected electrical

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signal and use the waveform of the electromyographic signal to monitor the human facial data, which can later be developed into a wearable orthodontic instrument. monitoring instruments.

In order to achieve the above purpose, we need to collect the electromyographic signals from different locations on the face of adults under the state of jaw movement, and the corresponding data can be obtained by overlaying their faces with an eight-channel multipurpose physiological recorder before we can guarantee that the energy collector is generating a stable electrical signal. On the other hand, it can help to better understand and test whether the piezoelectric sheet is suitable for human facial implantation from a medical perspective, including the energy harvesting of the piezoelectric device. In this study, the measurement of myoelectric signals of some muscles of the adult face, the way of energy storage and conversion power of the piezoelectric energy collector, and the prediction of the surgical position in the hypothesis will be described. It will also conclude with a conjectural analysis of the hypotheses presented in the study in anticipation of the next research advancement.

2. Measurement of electromyographic signals

Test subjects One0 random professional adult on campus was selected as the sample, 7 males and 3 females, aged 19-20 years. The face was symmetrical, no bad habits such as smoking, no history of orthodontics, no neurological diseases such as facial palsy, no abnormal ringing, and an opening of 33-46 mm.

Apparatus The PLUX eight-channel multi-purpose physiological recorder sold by Beijing ProEast Technology Company is configured as an eight-channel electromyography recording and analysis system.

Testing method 1. the test person's face clean, head upright. 2. the test position wipe with 75% ethanol. 3. the instrument comes with the grounding electrode paste paste in the middle of the forehead in the test, the recording electrode and the reference electrode are 15-20mm apart. next paste to the anterior temporalis muscle bundle, posterior temporalis muscle bundle, bite muscle, diastasis anterior belly respectively. The specific position was adjusted according to the face of different people.4. The parameters set for EMG recording were sampling rate of 2k/s, sampling two into 1mV0, and scaling ratio of 1000:1.

Test procedure The electromyographic activities of the anterior temporalis bundle (TA) on both sides, posterior temporalis bundle (TP) on both sides, occlusal muscles (MM) on both sides, and `anterior diastasis (DA) on both sides of the test subjects were recorded in the mandibular postural position, anterior tooth-to-edge, maximal mandibular anterior extension, bilateral chewing, maximal mouth opening, and post-swallowing teeth clenching actions.

Data recording The EMG signals were acquired and evaluated with the Hongke DASLab software, and the results are$\bar{x} \pm s$ indicated.

3. Data result

Interpretation The average EMG value, peak and amplitude are displayed as standard quantities of EMG signals and are able to determine whether a stable electrical signal can be generated. And according to the comparison of the above three data values, the difference between its each masticatory muscle in the mandibular movement is significant and can be used for the reference of the implantable energy collector.

Mean EMG value is the average of instantaneous EMG amplitude over a period of time, which is a special index reflecting the change of sEMG signal amplitude, and its change mainly reflects the number of facial muscle units activated during muscle activity, the type of muscle units involved in the activity, and the degree of synchronization. the results of the analysis of the mean EMG values of sEMG of masticatory muscles in different states of the jaw in one0 test case are shown in Table 1.

Peak The electrical signal value of the maximum energy released by the muscle during each contraction reflects the intensity of muscle contraction and is the performance of the masticatory muscle. the average peak value of the EMG of the surface of the masticatory muscle in different states of the jaw in one0 test subject was analyzed in Table 2.

Amplitude The difference in amplitude between the maximum positive and negative peaks within a defined time frame. Reflects the intensity of the EMG signal, and the number of muscle units involved. 10The results of the analysis of the average amplitude of the surface EMG of the masticatory muscles in the different states of the jaw in the case test subjects are shown in Table.

Table 1:Analysis of the mean EMG values of the surface EMG of the masticatory muscles at different states of the mandible (μV , n=10)$\bar{x} \pm s$, n=10)

	Posture position	Front tooth to edge	Maximal mandibular advancement	Chewing	Large open mouth	Gnash your teeth after swallowing	F value
RDA	13.43±6.53	26.42±15.45	25.31±12.41	94.41±82.35	71.10±43.21	20.13±6.14	8.08
LDA	15.51±11.35	40.81±19.23	36.41±19.41	109.16±104.12	225.80±415.52	27.48±25.61	2.95
RMM	16.46±11.16	15.23±5.32	14.17±6.58	91.07±72.51	54.08±35.97	28.16±14.12	8.44
LMM	12.76±11.89	20.41±7.36	25.51±15.46	71.68±35.82	252.25±431.11	22.14±8.03	2.57
RTA	9.89±4.84	12.41±5.37	14.23±4.61	45.01±21.61	34.50±20.38	23.11±10.14	18.81
LTA	10.41±3.75	11.09±4.14	13.17±5.46	32.56±19.01	46.33±33.51	22.85±10.66	7.41
RTP	16.41±13.51	13.68±3.61	22.95±17.17	39.24±13.02	30.24±27.04	17.21±8.12	6.65
LTP	20.71±18.71	14.71±3.12	19.41±4.58	54.01±48.05	42.12±51.41	18.51±4.31	4.88
F-value	1.95	10.14	9.12	3.45	1.65	1.48	

Table2： Peak analysis of masticatory muscle surface electromyography during different states of the mandible (μV , n=10)$\bar{x} \pm s$, n=10)

	Posture position	Front tooth to edge	Maximal mandibular advancement	Chewing	Large open mouth	Gnash your teeth after swallowing	F-value
RDA	14.43±7.53	26.42±17.45	25.31±12.41	64.41±52.35	86.10±33.21	21.13±9.14	11.08
LDA	14.51±10.35	40.81±39.23	36.41±19.41	69.16±56.12	205.80±225.52	29.48±25.61	4.95
RMM	15.46±10.16	15.23±5.08	14.17±6.58	57.07±32.51	104.08±71.97	20.16±4.12	11.44
LMM	11.76±11.89	23.41±21.36	25.51±15.46	47.68±21.82	182.25±231.11	19.14±8.03	4.57
RTA	9.89±5.84	16.41±5.37	14.23±4.61	31.01±17.61	41.50±24.38	18.11±6.14	11.81
LTA	9.41±4.75	14.09±4.14	13.17±5.46	23.56±9.01	36.33±14.51	14.85±6.66	15.41
RTP	15.41±13.51	18.68±13.61	22.95±17.17	31.24±12.02	44.24±40.04	18.21±10.12	2.65
LTP	21.71±14.71	17.71±9.12	19.41±4.58	35.01±27.05	50.12±27.41	18.51±13.31	5.88
F-value	0.94	2.58	5.31	3.45	3.23	1.48	

Table3： Mean amplitude analysis of the surface EMG of the masticatory muscles during different states of the mandible (μV , n=10)$\bar{x} \pm s$, n=10)

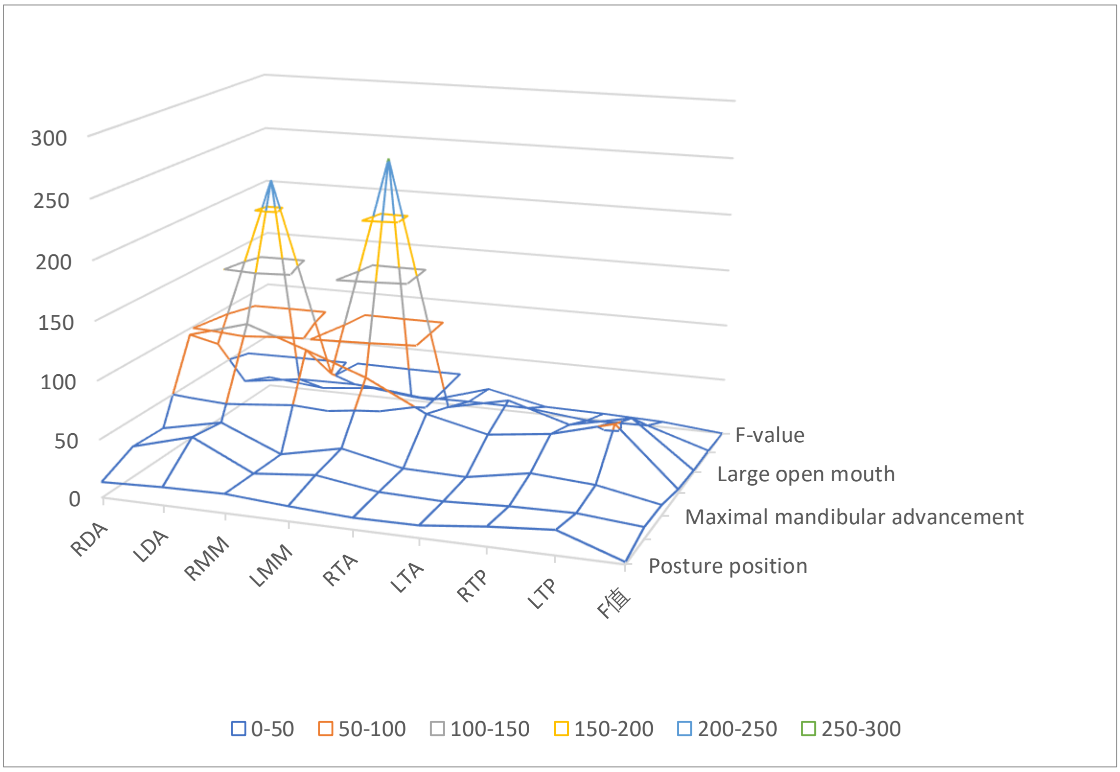
	Posture position	Front tooth to edge	Maximal mandibular advancement	Chewing	Large open mouth	Gnash your teeth after swallowing	F-value
RDA	13.43±6.53	26.42±15.45	25.31±12.41	94.41±82.35	71.10±43.21	20.13±6.14	8.08
LDA	15.51±11.35	40.81±19.23	36.41±19.41	109.16±104.12	225.80±415.52	27.48±25.61	2.95
RMM	16.46±11.16	15.23±5 .32	14.17±6.58	91.07±72.51	54.08±35.97	28.16±14.12	8.44
LMM	12.76±11.89	20.41±7.36	25.51±15.46	71.68±35.82	252.25±431.11	22.14±8.03	2.57

RTA	9.89±4.84	12.41±5.37	14.23±4.61	45.01±21.61	34.50±20.38	23.11±10.14	18.81
LTA	10.41±3.75	11.09±4.14	13.17±5.46	32.56±19.01	46.33±33.51	22.85±10.66	7.41
RTP	16.41±13.51	13.68±3.61	22.95±17.17	39.24±13.02	30.24±27.04	17.21±8.12	6.65
LTP	20.71±18.71	14.71±3.12	19.41±4.58	54.01±48.05	42.12±51.41	18.51±4.31	4.88
F-value	1.95	10.14	9.12	3.45	1.65	1.48	

4. Analysis results

Power spectrogram analysis By itself, the sEMG signal we choose to measure is a one-dimensional voltage time series signal guided and amplified by electrodes, which is a non-stationary, non-linear electrical signal, but the difference between surface electrodes and pin electrodes by itself, plus the simultaneous generation of EMG signals from facial activity units can cause problems for single-site measurements, but its EMG signal reflecting the muscle activity state is still fine. It only requires us to extract and analyze its fidelity information. The average amplitude of the surface EMG of the masticatory muscles in different states of the mandible is analyzed in Table 4.

Table4 :Histogram of the mean amplitude analysis of the surface EMG of the masticatory muscles at different states of the mandible



Surgical location analysis Table 4 specifies two suitable locations for stable EMG signal generation, among the six common oral postures in life the anterior and posterior temporalis bundles have no way to maintain stable electrical signal output, so the remaining available options are the anterior diastasis and the occlusal muscle, from the values, the anterior diastasis has a strong ability to maintain stability and the difference between the upper and lower amplitudes is not large, the occlusal muscle has a high peak maintenance time but the amplitude

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difference is too large. Therefore, it is not easy to judge whether both can provide a stable energy signal for their energy collectors alone, but it will be obvious from the analysis of the surgical position. Figure 1 shows the distribution of the human facial muscles. The ⑭ is the bite muscle, which has a good surgical location and a large bearing area, and is close to the implantation position behind the ear, but the anterior belly of the bicipital muscle is in the lower part of the ⑱, which is the part where the jaw is connected to the cartilage of the neck. Therefore, the occlusal muscle was basically determined as the surgical site.

The normal cochlear implant procedure involves making a 3cm incision behind the auricle, followed by a simple mastoid chisel incision, grinding away to expose the facial saphenous fossa, grinding out the implant after seeing the round window niche, grinding out a graft bed, and inserting the cochlear implant electrodes. Then, in order to install the energy collector without increasing the surgical risk, we choose to make a 2 cm incision along the incision to the mandible, from which the energy collector is probed into the surface of the occlusal muscle, followed by stitching on the surface of the occlusal muscle, which follows a diagonal suture pattern, and then connect it to the cochlear implant along the mandible for internal self-powering. The suturing or removal of the occlusal muscle in known clinical cases does not interfere with the facial nerve or normal eating, and may be slightly uncomfortable for the first two days, with the discomfort subsiding over time.

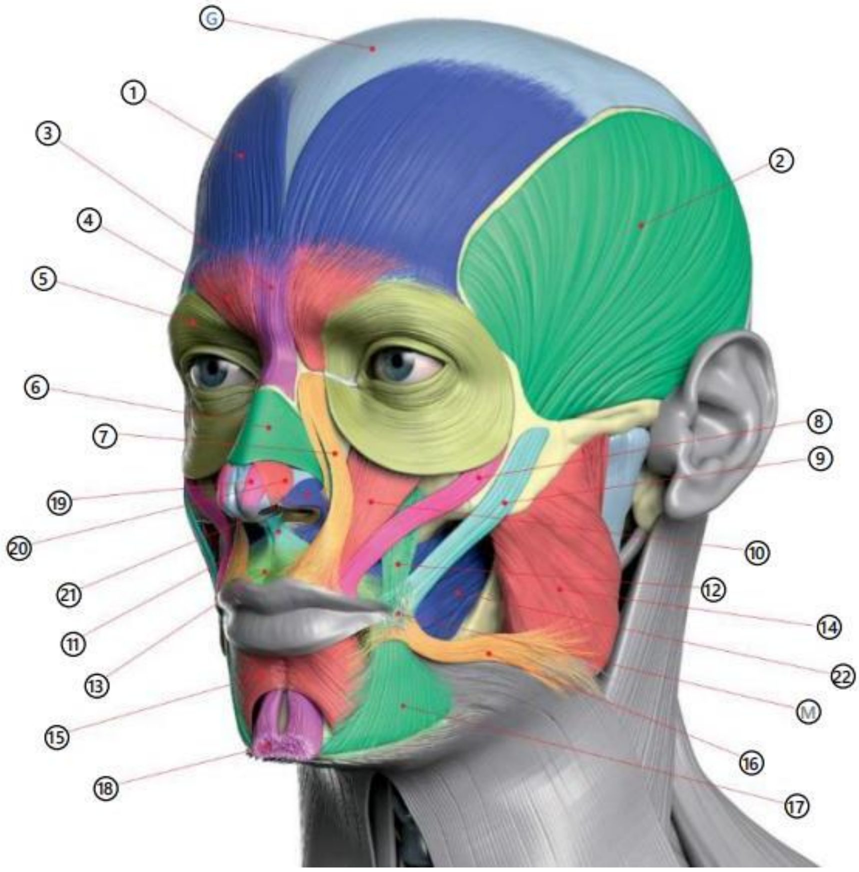

Fig 1:Human facial muscle distribution

5. Piezoelectric devices

The substrate material of UFEH is PZT, which is a polycrystal made by sintering lead dioxide, lead zirconate, and lead titanate at high temperature of 1200Celsius. The positive piezoelectric effect and negative piezoelectric effect of its material can meet the requirement of collecting kinetic signals from living organisms. Then the top electrode is composed of Au/Cr (200nm/10nm), slicing the PZT strips into daredevil50μm *mm2. The bottom Pt/Ti electrode size is$140\mu m * 2mm$. The electronic components are etched in a polydimethylsiloxane (PDMS) organic matrix layer.

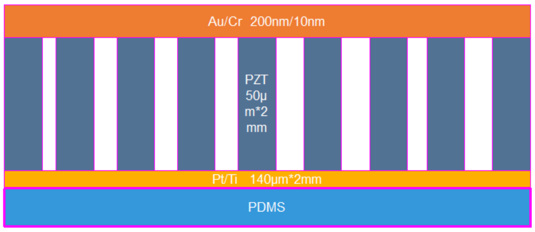

Figure 2:Principle model of piezoelectric energy harvester

Transfer printing methods Electronic components are etched into polydimethylsiloxane (PDMS) organic substrate layers, but this step is often difficult and requires flexible impressions for large-scale component or material transfer from one substrate to another. And the transfer adhesion of which needs to be tuned. As for this aspect is very wide application space, so we will not discuss it here.

Preliminary study of the piezoelectric energy harvester As a part that can be developed to tell, no relevant biological experiments have been conducted. However, in accordance with the previous measurement and simulation of its human facial EMG signal, we gave the table5 to simulate the data, and through simulation to determine whether implantable experiments can be conducted, which is more promising at present.

Table5:Corresponding position of masticatory muscle surface electromyography and its output voltage in different states of mandible

	Peak potential (V)
RDA	1.3
LDA	1.5
RMM	1.6
LMM	1.2
RTA	0.9
LTA	1.0
RTP	1.6
LTP	2.0
F-value	1.95

6. Discussion and Results

The piezoelectric effect is the process by which electrical signals are collected and utilized. But the way the body generates electrical signals is often due to muscle kinetics. Implantable medical devices are significantly improved if they rely on piezoelectric materials to convert them into electrical energy. Most of the previous implantable medical devices suffer from insufficient power supply, and even artificial hearts and cardiac vibrators need to be replaced over the years. And the secondary surgery will cause great harm to their patients. But the experiments in the last four years have proved that the powerful force of the heart can be used as a source of electrical energy for piezoelectric materials, which can realize the power supply of the heart. Then the part other than the heart either has no way to ensure the power supply at all times because of the muscle tremor problem, or the voltage of the power supply cannot be maintained stable. Therefore, our preliminary study of implantable piezoelectric energy harvesters in the human face is based on two points. On the one hand, the constant tremor of facial muscles can ensure the constant energy supply, and on the other hand, the huge energy generated can ensure the commercialization and maintenance of stability. The current piezoelectric energy harvester is designed and manufactured by Tsinghua University, using

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transfer technology to realize the combination of PZT and flexible PDMS matrix, which is flexible and ductile with the structural instability of PZT strips, and its special adaptability also makes it meet the criteria for implantation in human body.

In summary, nano self-generating generators made of piezoelectric materials are capable of turning mechanical energy into electrical energy in human life. This is especially true for portable electronic devices and medical devices. In the case of implanted organs or assistive medical devices, it is more important to find the source of energy from inside the human body. Preliminary studies have proved that the materials of such devices can be well adapted to the energy transfer from living organisms, but it is also important to consider whether perfect transplantation and subsequent experimental problems can be achieved.

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