Abstract and Specific Aims

Project Proposal

This project will add a second mode of functionality to the previous Gum Sounder project. This project explores several methods of measuring the force applied by the tip of the Gum Sounder tool. These methods are measuring the resonant frequency shift of the piezoelectric crystal as pressure is applied to it, measuring the flexure of the tool through the use of strain gauges, as well as building a cleanable handle in which the tool is fixed about a fulcrum and allowed to deflect against a spring, or for the fulcrum to magnify the force at the tip against a force sensor built into the handle.

Project Goals

The current goal of the research is to provide information to the user regarding the force applied to the gum tissue as its thickness is being measured. This will allow the user to collect a more accurate thickness of the gum tissue. The implementation of this feature within the device may allow the tool to be used in the dental profession as a replacement of more expensive and risky means of measuring tissue thickness.

Introduction

Gum Sounder Application

The gum sounder may one day be used by dentists to evaluate patients for dental implant candidacy. Before a patient may receive a dental implant the edentulous ridge (tooth bearing crest of the jawbone) must be surveyed to ensure that sufficient bone remains to support the dental implant, because after tooth extractions the structure of the edentulous ridge may change substantially (Pietrokovski 1975; Schropp et al. 2003). The device may be used in conjunction with a caliper measurement of the thickness of the jaw at the root of the tooth. The gum thicknesses are measured at the inside and outside of the jaw and both are subtracted from the caliper reading. These measurements may be used to construct a profile of the jawbone. This profile is used to determine a patient's candidacy for dental implants. The dental implants are then used as anchors for crowns.

Current Tools in this Application

While ultrasonic measurements of gum tissue thickness have been performed before(Eger et al. 1996), the spatial precision of prior tools have been limited due to the large coupling area of the ultrasonic transducer.

The methods used to visualize the edentulous ridge are digital(finger) clinical examination, diagnostic casts, tomographic analysis, of computerized tomography scan(Eckert et al. 1989). Of these procedures only the computerized tomography scan can produce a detailed edentulous ridge profile. This procedure is not ideal because it subjects the patient to a radiation associated risk(Nat'l Cancer Inst. 2003). This procedure can also be quite expensive and the equipment is not usually located in the dentist's office. So this procedure may lengthen the time a patient spends with a missing tooth.

Another method of determining gum tissue thickness is the use of a manual probe in conjunction with a dental clamp, used to pierce the gum tissue and periosteum(Franklin, Goode, Harkacz, 2009). This procedure is painful, and carries the risk of infection. These aspects make the procedure expensive, as the procedure would include anesthesia, as well as the higher cost of a more experienced dentist qualified to operate with greater risk.

Justification for Device Refinement

The historical use of ultrasonic measurements of gum tissue thickness have not been used in the evaluation of patients for dental implant candidacy, CT scans have remained the dominant method of construct a detailed jaw bone profile necessary for complete evaluation. Therefore a device which can measure the tissue thickness of a smaller area may be useful dental implant candidacy evaluations for patients who may be averse to the risks associated with a CT scan.

A more refined ultrasonic gum tissue thickness tool will be useful in the profiling of jawbone widths. It may also one day eliminate the need for a patient to undergo a CT scan as part of the evaluation for dental implant candidacy.

Area of Device Refinement

The device has seen previous development by a senior design team in the Engineering department of the University of Alaska Anchorage, also working under the guidance of Professors Anthony Paris, Jens Munk, and John Lund. The previous work done was to implement an ultrasonic tissue thickness measurement device with a fine tip, of diameter .060 inches or 1.5mm. This new device configuration would allow better jawbone profiles to be constructed, but it also presents a new problem. When the tip was applied to porcine gum tissue a depression was made in the tissue. This depression takes away from accuracy of the tissue thickness measurement as it reduces the thickness of the . A force as small as 1 pound applied by a circular surface with a diameter of .060 inches is equivalent to approximately 350 psi. That’s more than double the pressure in a vehicle tire. This result shows that a combined method for measuring the applied force could greatly assist a dentist in the assay gum tissue thickness and the resulting construction of edentulous ridge profiles.

Experimental/Project Design

Previous Work

This project expands on the previous work Doug Franklin, Kelvin Goode, and Orest Harkacz, Jr. This work was done under the guidance of UAA School of Engineering Faculty Dr. Anthony Paris, Dr. Jens Munk, Dr. John Lund, as well as Boise Oral and Maxillofacial Faculty Dr. Bruce Morrison, and Dr. Kevin Kempers. This group was able to develop a gum tissue thickness sensor based on commercial hardware and software. The group used a sonopen with a delay line supplied by Olympus. The device possesses a circular coupling interface with a diameter of 1.5mm, this allows for greater versatility in the measurement of tissue thickness between teeth over the ultrasonic gum tissue thickness measuring devices used in the past. The work also included a Labview interface for monitoring the waveform of the reflected signal as well as the display of the final calculated tissue thickness.

Proposed Work

The goal of our senior design work is to improve upon this previous work by adding functionality to the device allowing it to measure the amount of force applied by the user of the gum sounder. The device will be further improved by providing the dentist with some peripheral feedback of the force. Our work will also incorporate a keystroke mechanism for acquiring a data point once the desired tool orientation and force have been achieved.

The project will investigate peripheral force feedback methods by incorporating a light of varying brightness and a tone of varying pitch. A peripheral feedback system may be preferred by the operator to shifting focus between the manipulations of the tool and paying attention to the interface on the screen of the PC. The Labview code will also be modified to accept a keystroke which will log the current values of thickness and force simultaneously. In the future this functionality may be triggered by the tapping of a foot pedal so as to require a minimum effort of the operator. This functionality will further increase the general usability of tool in the practice of dentistry.

Force Measurement

The force measurement part of our project has been divided into four different sections: Andrew Cochrane is researching resonance in a piezoelectric crystal; Brian Oliver is researching strain gauge elongation, Elliott Larsen is researching mechanical force amplification in conjunction with a force sensing resistor, and Thomas Van Thiel is researching displacement against a spring in conjunction with a rotary encoder.

Cochrane is looking for the best method to measure the applied pressure using the piezoelectric crystal embedded in the sonopen. He will explore signal analysis techniques to measure resonant frequencies of the sonopen because there is evidence of a linear relationship between the resonant frequency of a piezoelectric crystal and the pressure applied to it. Another means by which the pressure may be measured is by acquiring the DC offset produced by applying pressure to a piezoelectric crystal. Dr. Jiashi Yang conducted research which was published in his book, <u>Analysis of Piezoelectric Devices</u>, displaying the linear relationship between resonant frequency and pressure. Dr. Yang said that “Piezoelectric pressure sensors can be made by measuring either pressure induced charge or frequency shifts.” In the effort to extract pressure information from the waveform, the reflections from the separate material interfaces will be analyzed in the search for pressure related frequency shifts. If none are found, the signal that is generated by the pulser/receiver card and sent to the sonopen to excite the crystal will be observed by a circuit designed to draw as little energy as possible from the system and provide the shape of that signal to Labview. Once Labview has the shape of the input signal, it can compare it shape of the returned signal in order to obtain a frequency response of the entire system comprised of the sonopen, the piezoelectric crystal, the delay line, the tissue, and the bone. This frequency response can then be analyzed for frequency shifts of any of the individual mediums in the system.

Oliver is researching methods of using a strain gauge to help determine the force applied by the gum sounder. According to AllAboutCircuits.com, “If these stresses are kept within the elastic limit of the [gum sounder] (so that the [gum sounder] does not permanently deform), it can be used as a measuring element for physical force, the amount of applied force inferred by measuring its resistance”. The strain gauges will be applied to the body of the gum sounder and organized electrically in a Wheatstone bridge. This configuration will allow force measurements by the gum sounder as a change in electrical resistance while allowing the simultaneous capture of gum tissue thickness. The electrical resistance will affect an input voltage, producing an output voltage which is related to the applied force. The measured change in resistance is related to the force applied to the end of the sonopen.

Larsen is researching mechanical force magnification about a fulcrum. This method will magnify small forces at the tip of the sonopen while measuring them near a fulcrum at the sonopen’s base. These mechanically magnified forces will be measured by a force sensing resistor built into an external handle capable of clamping onto the base of the sonopen. The force applied to the tip of the sonopen will be related to the resistance of the sensing element, which may be interpreted with a voltage source, a voltage dividing circuit and some Labview code.

Van Thiel is researching displacement against a spring in conjunction with a rotary encoder. The encoder will relay information about the angular displacement of the gum sounder within a manufactured handle. The applied force may then be determined by multiplying the spring constant by the angular displacement by the moment arm where the spring has been placed.

Labview Data Acquisition

Both small signals measurement devices will be incorporated into circuits which are designed to use op amps in the magnification of the relevant voltage signals. These signals will be available in Labview through the use of a National Instruments USB-6008 Multifunction DAQ (Digital Acquisition Unit). The rotary encoder signal may be read directly by the NI DAQ. Any extra signals needed in the analysis of the piezoelectric crystal may be captured by the oscilloscope card already present in the host PC.

The Labview Interface

The Labview interface is thus far an integral component of the tool. This interface will be relied upon to do all signal to force calculations. The interface will also be modified to provide output for the proposed visual and audial force feedback improvements. Finally the interface will be modified to include a measurement log, where a measurement will be stored upon the stroke of a key.

Handle Design and Prototyping

A suitable handle will be designed and constructed for the measurement modes of mechanical force amplification and rotation angle measurement. The case will be printed with UAA SOE rapid prototyping equipment while the rest of the fabrication will be done by the group, using parts acquired through this grant and tools available to engineering students.

Anticipated Results

Final Outcome

We expect to produce a device capable of simultaneously measuring force and tissue thickness. While the tissue thickness will continue to be measured by the ultrasonic transducer, we expect to investigate several methods of measuring force. We expect to produce at least one medically clean and reliable method for electric measurement of force. We plan to incorporate this method of force measurement into the device in such a way as to make the device an attractive option for dentists who practice the evaluation of candidacy for dental implants.

Peripheral Indicators

A peripheral indication of the force will be implemented as a lighted indicator whose brightness will vary with force, or indicating when a force threshold has been crossed. A second possible peripheral indicator of pressure is a sound whose pitch varies with applied pressure.

Capturing the Measurement

We will incorporate a one keystroke method of recording a combined thickness and force measurement. This may be used in the development of a software platform for the dental profession which may assist the dentist by graphically relating the recording to its position in the patient’s mouth.

Learning Experience

While working to produce these measurement methods, the members of our group will learn about working with National Instruments Labview software, strain gauges, potentiometers, force sensors, electric circuits, high quality springs, precision fulcrums, and producing tools for use in a sterile environment.

Item	Unit Cost ($)	Quantity	Total Cost
Sonopen V260-RM	520	1	520
USB Acquisition Device	169	1	169
Op Amp (HighPrecision) 4 opamps/unit	11.85	3	35.55
Op Amp (High Frequency)	3.67	2	7.34
Circuit Prototyping Boards	2	10	20
Electrical Connectors	20	1	20
Strain Gauge order of 5 minimum	14.686	9	132.174
Medical grade glue	30	1	30
Bicolor wiring spool	10	1	10
4pk force sensing resistors	75	1	75
Rotational encoder	27	1	27
Assorted Springs	10	1	10
Adjustable Resistors	2	10	20
Op Amp Circuit Resistors	10	1	10
Miniature Tool Bearing	10	4	40
Semisoft Clamping Mechanism	50	2	100
Rapid Prototyping Material	50	2	100
Assorted Parts for rotation mechanism completion	50	2	100
	Subtotal Cost		1426.064
30% of Subtotal for Shipping and Expediting Expenses	427.8192		427.8192
	Grand Total		1853.8832

Justification

Sonopen V260-RM: This is the piezoelectric transducer
USB Acquisition Device: This will be used to capture various signals for use with labview
Op Amps: Will be used to condition signals before being captured by the USB DAQ
Circuit prototyping boards: Will be used to build circuits for signal conditioning
Electrical Connectors: Cord end plugs for connecting wires
Strain Gauges: Used to measure strain
Medical Grade Glue: Used to glue strain gauges to the piezoelectric transducer
Bicolor wiring spool: Used to connect instrumentation to computer.
4pk force sensing resistors: A force sensing transducer
Rotational Encoder: A rotation sensing transducer
Assorted Springs: For picking the spring that works the best with the Rotational encoder
Adjustable Resistors: For tuning the Op Amp conditioning circuits
Op Amp Circuit Resistors: For the Op Amp conditioning circuits
Miniature Tool Bearings: To supply a low friction moment arm
Semisoft Clamping Mechanism: To attach a handle to the sonopen
Rapid Prototyping Material: To manufacture a prototype handle
Assorted parts for rotation mechanism completion: Unknown parts needed to complete the handles
30% of Subtotal will be used for shipping and other unforseen expenses associated with prototype fabrication

Acknowledgment

Our Senior Design group thanks Dr. Anthony Paris, Dr. John Lund, Dr. Jens Munk, Dr. Bruce Morrison, Dr. Kevin Kempers, Doug Franklin, Kelvin Goode, and Orest Harkacz Jr. for their efforts in this research development.

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Project Timeline

October 7th, 2011	Outline individual sensing method design criteria Gather reference schematics for circuit designs
October 14th, 2011	Gather reference material for written report Prepare analytic models of each sensing mechanism
October 21st, 2011	Compile detailed parts lists Engineering plans for each sensing method formalized
October 28th, 2011	Rough draft of report completed Complete computer models for rapid prototyping of housings Complete circuit schematics and kinematic diagrams
November 4th, 2011	Order parts (budget expenditure) Complete rapid prototyping
November 11th, 2011	Build circuits Complete all device assembly
November 18th, 2011	Write Labview code to interpret signals from each sensing mechanism Complete evaluation/comparison of sensing methods
November 25th, 2011	Revise Report
December 2nd, 2011	Complete comparison of force sensing methods
December 9th, 2011	Complete final report and prototype