Wireless Sensor Network for A Bite Force Recorder

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Abstract

Maximum bite force of an individual is one of the most important perimeters which correlate with the wellbeing of the oral health of a person. The measurement of bite force can provide a useful data for the evaluation of jaw muscle functions and activities. It is also an adjunctive value in assessing the performance of a dental prosthesis. There are many bite force recorders in the market, however, the devices have many drawbacks in terms of accuracy, reproducibility, high costs, and infection control for intraoral application, which further limit its usage and effectiveness. The purpose of this innovation is to develop a wireless, handy, cost effective and reliable bite force recorder device in which can be produced in-office using a 3-D printer. Arduino Nano microcontroller connected to a Bluetooth module was used for a wireless connection to a smartphone. The bite gauge was specially design using computer aided design software and produced using 3-D printer. Flexi force™ sensor system that was attached to the bite gauge was used to measure the bite force. The consistency and accuracy of the bite force recorder was reaffirmed by laboratory calibration and the result showed good linearity as well as excellent repeatability of the forces reading. Pilot study on human subjects was conducted to see the range of normal bite strength in adults. The positive demonstration found in this study suggests reasonable feasibility of using this device for dental application.

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Introduction

The bite force value is a reliable functional health indicator of the oral mastication system[1].

It is generated from the mixed actions of the jaw closing muscles and modified by jaw biomechanics and reflexes. The bone, muscles, teeth and nervous system are all have an effect on the bite force. Therefore, any alteration of these systems will influence the biting ability of an individual[2,3]. In dentistry, there are various reasons to measure bite forces value. These include understanding the underlying dynamics of masticatory process[4], analysing the physiological characteristics of jaw muscles[5], researching the impact of various physical factors such as gender, age, height and weight on occlusal forces[6,7] and providing reference values for research on the biomechanics of dental prostheses[8,9]. In addition, bite force analysis has been considered by some to be clinically relevant in assessing the efficiency and therapeutic effects of the prostheses[10,11]. It was also suggested to be measured in the diagnosis and treatment of temporomandibular joint disorders (TMD) (Todic, Martinovic, Pavlovic, Tabakovic, & Staletovic, 2019).

In the past, a lot of bite force measurement devices were developed and published in the literature. However, many of them presented with several problems in term of accuracy and reproducibility. Some of the devices are not user friendly and has improper infection control for intraoral application[12-15]. In the recent trend, a large range of sensors have been integrated to calculate human bite force as

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it can provide an accurate reading. One of the examples is T-Scan, a commercially available device which uses a pressure sensitive sheet sensor that is capable of assisting dentists in carrying out a full occlusive examination on their patients. This system has been tested and validated by da Silva Martins, Caramelo, da Fonseca, Nicolau[16] , and has been widely used by the clinicians nowadays. However, the T-Scan system is expensive from financial point of view, especially when full arch occlusion analysis is not indicated.

Single tooth bite force measurement can be performed using an appropriate transducer [17, 18] . Single tooth transducer allows the measurement of the bite force corresponding to a single natural or prosthetic tooth[19]. This method seems to ignore oral function as a whole, but it appears important for a proper quantification of the actual effect on individual tooth or prosthesis. Therefore, the aim of this study is to devise an optimised design of a novel bite force recorder that is wireless, cost effective, user friendly, handy and able to produce a reliable bite force value for a single tooth area in which it can be produced in-office using a 3-dimensional (3-D) printer. The second aim is to assess the laboratory and clinical calibration of this novel bite force recorder.

Materials and methods

Development of the bite gauge using 3-D printing

The design of the bite gauge was made based on the recommendation of previous literature [2]. For infection control measure, the biting gauge was designed and made disposable and can be easily produced using 3-D printer. The separation between upper and lower teeth is 15mm and the width of the biting point is 10mm based on the average measurement of human individual tooth (Figure 1). The design of the 3-D printed parts was drawn using CATIA V5R20 software and printed using a 3-D printer (Zortrax M200, Zortrax, Poland). Acrylonitrile Butadiene Styrene or also known as ABS was used to produce the final product.

The design and function of the device

The bite force recorder was made light weight and wireless which can be connected to the smartphone through a Bluetooth wireless connection (Figure 2). Flexi force™ sensor system (Tekscan Inc, USA) was used as a measurement tool for this device. The sensor was attached to the designated slot in the bite gauge. Arduino Nano was used as the microcontroller for this device and connected to a Bluetooth module to give a wireless connection to the smartphone. The application on the smartphone was created using MIT AI2 Companion App inventor system. The electronic parts were placed in a small box, also produced from 3-D printer (Figure 3 and Figure 4). The device comprises of six main parts as follow:

1. 3-D printed part
2. Arduino Nano microcontroller
3. Flexiforce™ sensor
4. Bluetooth module
5. 2 x 3.7V Baterry LiPO
6. Smartphone

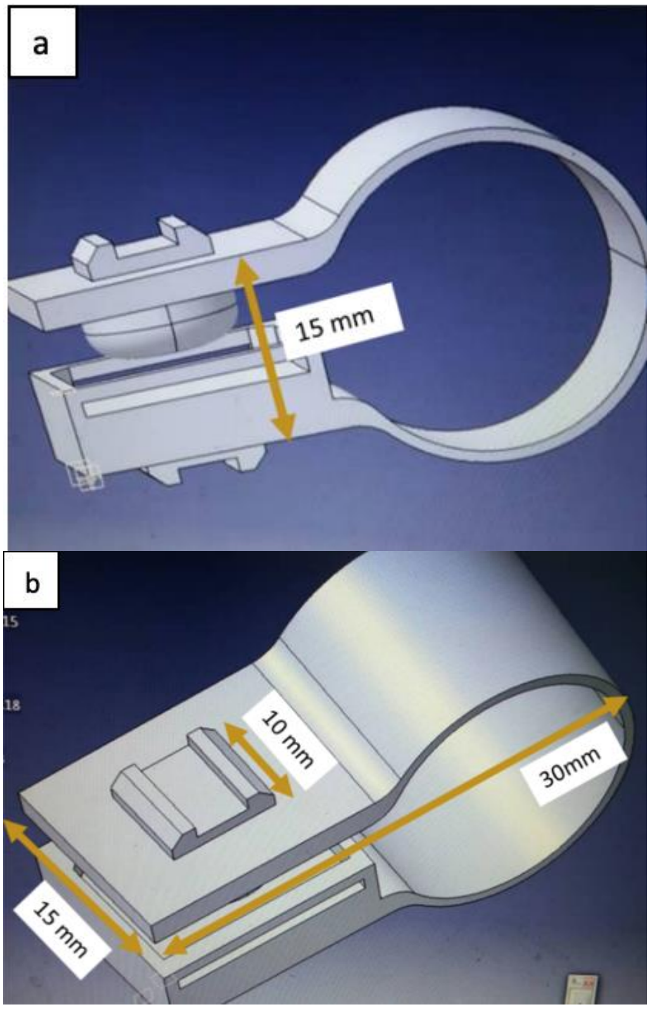

Figure 1: 3-D design of the bite gauge. a) Side view. b) Upper view.

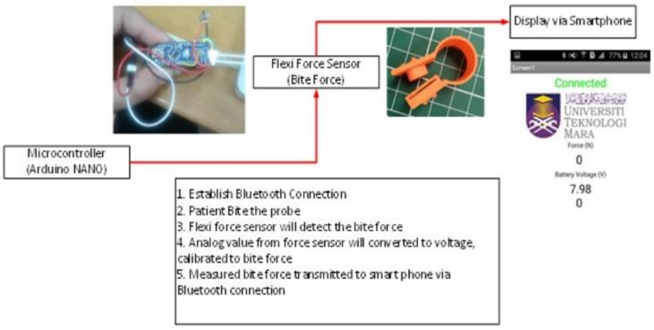

Figure 2: Flowchart of the device connection.

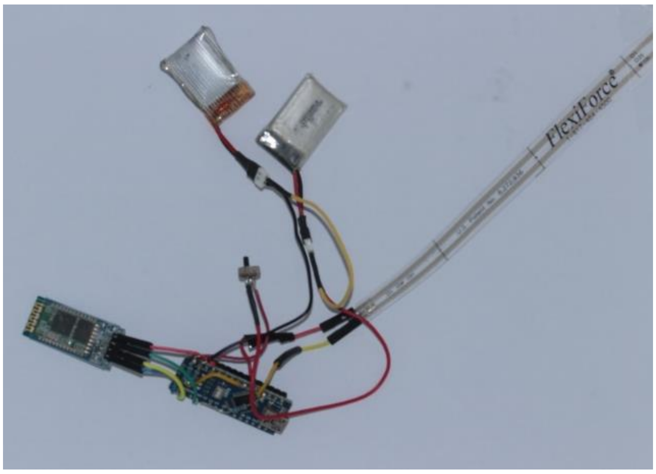

Figure 3: Electrical component of the device.

Figure 4: The 3-D print component.

Laboratory calibration

Laboratory calibration was conducted using the compression test on Universal Testing Machine (Shimadzu, Japan) to confirm the accuracy of force value produced from the device. The bite gauge is positioned in the centre of the platform screw jack. A chisel shape of the upper platform was chosen to simulate the shape of a tooth when biting. The force was applied at a crosshead speed of 1mm/min in the increments of 50N and load up to 500N in static force measurement (Figure 5). Three cycles of compression test were conducted to test the repeatability of the reading.

Another compression test was conducted using the same machine and instrument to investigate the fractured toughness of the bite gauge material. The force was applied at a crosshead speed of 2 mm/min until the bite gauge was fractured (Figure 6).

Figure 5: Laboratory calibration using Universal Testing Machine.

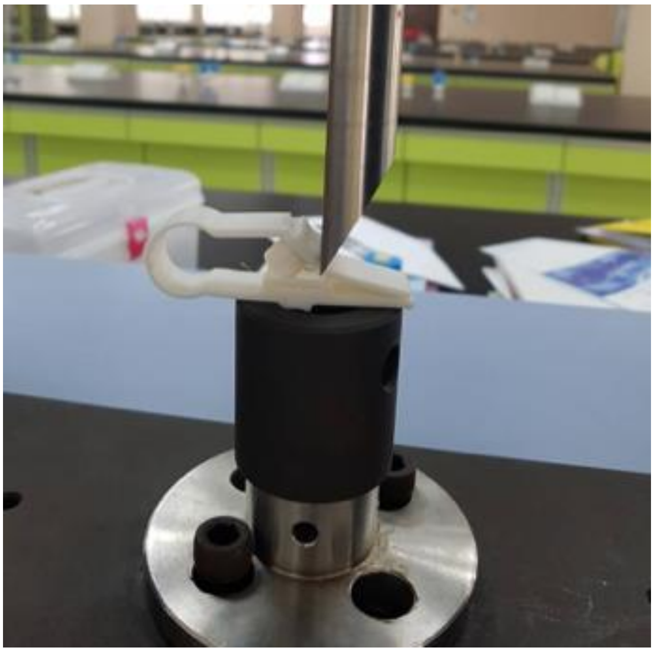
Figure 6: Fractured toughness test.

Clinical validation

Ethical approval was received from Universiti Teknologi MARA ethical committee prior to clinical test (600 – IRMI (5/1/6). The aim of this clinical validation is to reaffirm the accuracy in recording of the human maximum bite force value using this device. Ten adults volunteer subjects (5 males and 5 females) were participated in the clinical validation test after signing the written consent.The inclusion criteria for subjects selection were: age ranged from 25 – 35-year-old and the incisor tooth must be free from caries, restorations, periodontal disease and in Class 1 incisal relationship. The standardized protocol for measurement of maximum bite force were as follow:

1) The subjects were instructed to seat in a relax position on the dental chair with the Frankfort horizontal plane parallel with the floor.
2) The subjects were advised to replicate the bite at the biting point when they are biting on the bite gauge prior to data collection.
3) The subjects were asked to perform a maximum clenching on the bite gauge using central incisor teeth for three seconds and the measurement were repeated 3 times (Figure 7).
4) The quantitative data of the incisal maximum voluntary bite force (IMVBF) value was expressed in means ± SD.

Figure 7: Measurement of incisal maximum voluntary bite force on adult subject.

Results

Laboratory calibration

The accuracy and reliability of the force values were confirmed during the laboratory calibration. The data from the laboratory calibration were expressed in mean and standard deviation (SD) (Table 1). A near linear relationship between the applied force and measured resistance was observed in the calibration result (Figure 8). Excellent repeatability of the reading between 3 cycles of compression test was observed (Figure 8). During the fractured toughness test, it was noted that the biting gauge fractured after 3000N of force applied. The strain curve of fracture toughness test was illustrated in Figure 9.

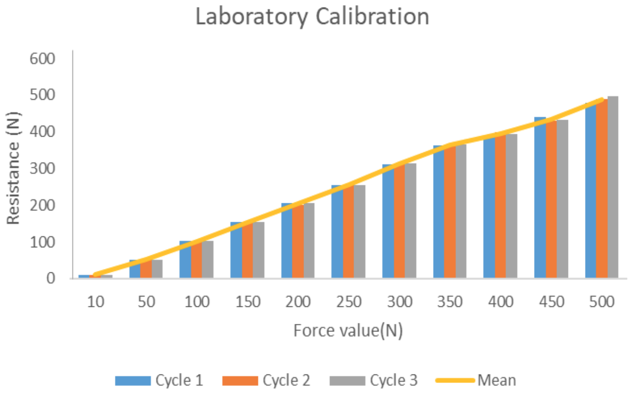

Figure 8: The graft from laboratory calibration result.

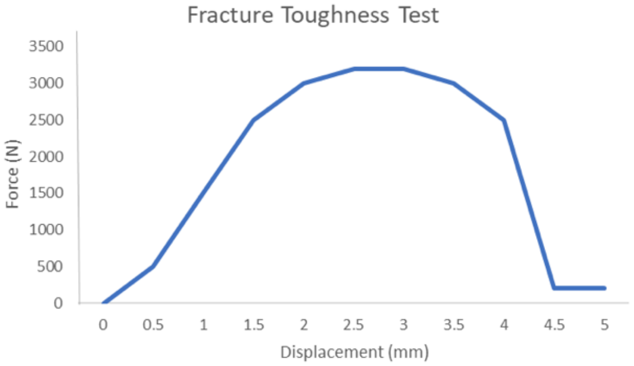

Figure 9: The strain curve of the bite gauge during fracture toughness test.

Clinical result

The clinical test has confirmed the reliability of this device to measure the human maximum bite force. It can be seen than the IMVBF value in males subjects was higher when compare to the females. The range values of IMVBF in this study were 118N – 170N for males and 65N – 112N for females with the mean ± SD were 152.6 ± 17.64 and 93.67 ± 14.22 respectively (Table 2).

Resistance (N)	Mean	SD
10	10.0	0
50	51.3	1.15
100	101.7	1.53
150	153.3	1.53
200	203.7	2.31
250	255.3	0.58
300	314.0	1.73
350	363.3	1.53
400	394.7	4.51
450	434.3	5.13
500	489.3	9.02

Table 1: The mean and standard deviation of laboratory calibration.

	IMVBF range (N)	Mean ± SD
Males (n=5)	118 N – 170 N	152.6 ± 17.64
Females (n=5)	65 N – 112 N	93.67 ± 14.22

Table 2: The force range with the overall mean of IMVBF(N) and their standard deviation (SD) according to gender.

Discussion

Previous studies have shown that there were several inherent problems when a bite force recorder was being reproduced. Without a good design and materials, the bite gauge produced is varied and do not meet the same standard. With the advancements of computer aided design and manufacturing technology, a precised custom products can be produced. In this study, the bite gauge has successfully been produced using 3-D printer. 3-D printing has the ability to share the designs and outsource the manufacturing process thus the product can be easily reproduced anywhere. Furthermore, it will reduce the overall manufacturing cost[20]. The finding of the fracture toughness test in this study also has shown that the ABS material used to produce the bite gauge is a suitable material as it is capable to sustain a high resistance forces up to 3000N which is beyond human maximum bite force[2].

A prefabricated and calibrated sensor (Flexiforce™, Teckscan Inc, USA) was used as the force measurement tool of this device. It contains a peizoresistive sensor which includes layers of materials that produce a measurebale change in electronic resistance under pressure load. The sensor can accurately measure the force up to 500N and it has 10mm diameter in size which adequate to cover the incisal edge or occlusal table of each individual tooth. It was recommended to use this sensor for measurement of bite force in previous studies[21-24]. The novelty of this device relies on the used of microcontroller board using Arduino Nano that act as the brain of this device, while the bluetooth module act as intermediary between the device and the screen viewer (smartphone). It was reported in many studies that Arduino Nano was a powerful tool in innovation of wireless gadgets[25-27]. In this study, a modification of this device system was proposed which include a wireless microcontroller with bluetooth module using Arduino Nano that can be connected to any smartphone to display the force reading. Hence, this modification offers to reduce the size of this device and cut in price of overall cost as the multimeter force reading machine is not needed. Besides, this device also provide a user friendly design and improve the infection control purpose which avoid the researcher having a direct contact to the patient while taking the reading.

The finding in the clinical validation test also similar with the studies conducted previously[28,29]. The present finding has reported the reliability of this device to produce an accurate reading. The mean and standard deviation (SD) of IMVBF produced using this device revealed within the normal range of incisal bite force which is 152.6 ± 17.64 in male subjects and 93.67 ± 14.22 in females subjects. These values were in agreement with another study by Regalo, Santos, Vitti, Regalo, de Vasconcelos, Mestriner Jr, Semprini, Dias, Hallak, Siéssere[29] which they measured IMVBF in adult white population using a similar commercial device and they found the values of the IMVBF were 150 ± 18 for males and 93 ± 15 for females.

Conclusions

In conclusion, the findings presented herein demonstrated a simple, handy and user-friendly fabrication of novel, economical wireless bite force recorder using 3-D printing. The sensor used displayed good linearity and excellent reproducibility with the capability to calculate a wide range of bite force up to 500 N. The positive demonstration in this invention of calculating the average bite force value of human subjects suggests reasonable feasibility of the use of this device for a single tooth bite force measurement.

Declaration of Interest

The authors report no conflict of interest.

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