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Force Analysis of an Automated Rapid Maxillary Expansion (ARME) Appliance

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***Abstract*—**An Automated Rapid Maxillary Expander (ARME) is a specially designed microcontroller-based orthodontic appliance to overcome the shortcomings imposed by the traditional maxillary expansion appliances. This new device is operates by automatically widening the maxilla (upper jaw) by expanding the midpalatal suture [1]. The ARME appliance that has been developed is a combination of modified butterfly expander appliance, micro gear, micro motor, and microcontroller to automatically produce light and continuous pressure to expand the maxilla. For this study, the functionality of the system is verified through laboratory tests by measure the forced applied to the teeth each time the maxilla expands. The laboratory test results show that the developed appliance meets the desired performance specifications consistently.

***Keywords*—** Maxillary Expansion, Microcontroller, Automated, Orthodontist, Force Analysis.

I. Introduction

Maxillary expansion used to correct maxillomadibular transverse discrepancies occurs through a combination of skeletal (orthopedic) expansion, which involves separating the maxilla at the midpalatal suture, and dental (orthodontic) expansion, which results from buccal tipping of the maxillary posterior teeth. The proportional of the skeletal and dental movement is dependent on the rate of expansion (rapid or slow) and the age of the patient during treatment [2-5]. The goal of palatal expansion is to maximize the skeletal movement and to minimize the dental movement [6, 7], while allowing for physiological adjustment of the suture during separation [8, 9].

Expansion appliances can be classified as rapid or slow expander. The rate at which the maxillary expander operates depends on the treatment process. Numerous expansion procedures have been applied currently. This ranges from slow maxillary expansion, semi-rapid maxillary expansion to rapid maxillary expansion (RME) and finally surgically assisted maxillary expansion. All of these treatment protocols have advantages and disadvantages, and the treatment selection depends on the clinician's choice.

At the cost of trouble and pain, the intermittent and incongruous force that a patient is putting on to his/her teeth is not of any help to the treatment. The problem mounts significantly when not only locating the small hole proves to be a demanding task, but the challenge to keep track and maintain the consistency of the screw-turns has also been of great concern to the clinicians. This inefficiency pertaining to patient compliance issue treatment is reduced by the development of pre-programmed microcontroller based Automated Rapid Maxillary Expansion (ARME) devices where it caters the need for a fully automated, hassle free system.

The ARME appliance was designed and developed using a combination of modified butterfly expander, micro gear and micro motor and also the microcontroller to produce light, continuous pressure on the midpalatal suture as shown in Fig. 1. This appliance is self-activated by micro motor under the control of a microcontroller, which means it can automatically expand the expander to the desired of amount. In this way patient errors such as missed, over-zealous or reversed screw-turns are eliminated, and the visit to the dental heath care provider is reduce to an optimized level.

Since the prototyping of automated RME have been completed, the safest way to go about testing the device at the moment is by applying the automated expander on the molars (of the dental cast) to see the distributed force on individual teeth.

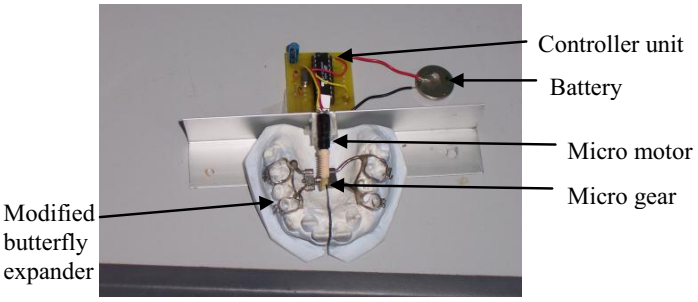

Fig. 1 ARME System

II. Experimental Methods

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In this experiment, a single force applied in the x-direction resulted in a translation in the x-direction. The steps involved in this experiment are: (1) to calibrate each strain gauge using dead weight method, (2) to build the measurement software, and (3) to run the system to collect the data.

The maxillary expander force-measuring device was built, consisting of four strain gauges (G_F =2, R_G = 120ohms), Wheatstone bridge circuit, 2 unit EMANT data acquisition and GUI interface software using LabView as shown in Fig. 2 and Fig.3. Each time the micro motor move to expand the maxilla, the force created by the expander was recorded in the GUI table as shown in Fig. 4.

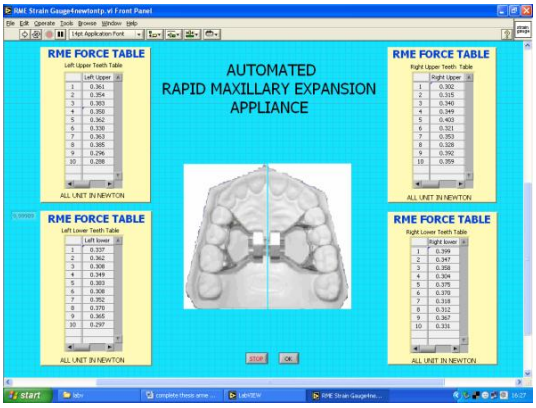

Fig. 4 ARME Force measuring software

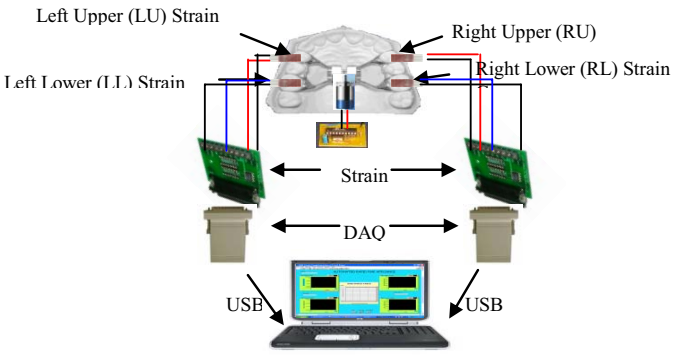

Fig. 2 System to measure Automated RME Force

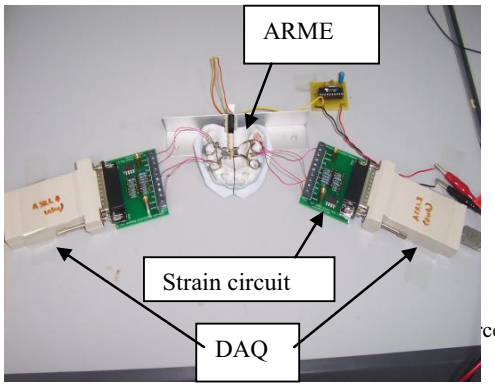

Fig. 3 System to measure Automated RME Force

The appliance is testing for working in 5 days. Two activations are occurred each day, means that for five day there have total ten activations occurred. For each activation, 90 degree of turning has occurred. The experiment was replicated for ten times (Test 1 to Test 10), giving a total day of experiment is 50 days continuously.

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III. Results

To analyze the repeatability and stability of the measurement, ten different tests had been conducted at different times. The forces created by the expander each time the micro motor moves to expand the maxilla for different four teeth are saved and analyzed.

One-way ANOVA is used to determine whether the data for force distribution for each dental cast tooth has a common mean, i.e., to determine whether the groups are actually different in the measured characteristic. Table I to Table IV shows the results of one-way ANOVA test for force distribution for each dental cast tooth. Figure 5 to Figure 8 shows the corresponding box plot for each force distribution.

TABLE I
ONE-WAY ANOVA TEST OF LEFT UPPER FORCE DATA

Source	SS	df	MS	F	Prob>F
Columns	0.00108	9	0.00012	0.16	0.9975
Error	0.06919	90	0.00077		
Total	0.07027	99			

TABLE II
ONE-WAY ANOVA TEST OF LEFT LOWER FORCE DATA

Source	SS	df	MS	F	Prob>F
Columns	0.003162	9	0.000351	0.32784	0.96371
Error	0.096452	90	0.001071		
Total	0.099614	99			

TABLE III
ONE-WAY ANOVA TEST OF RIGHT UPPER FORCE DATA

Source	SS	df	MS	F	Prob>F
Columns	0.001565	9	0.000173	0.24518	0.98658
Error	0.063857	90	0.000709		
Total	0.065423	99			

TABLE IV
ONE-WAY ANOVA TEST OF RIGHT LOWER FORCE DATA

Source	SS	df	MS	F	Prob>F
Columns	0.002399	9	0.0002666	0.25843	0.98383
error	0.092844	90	0.0010316		
Total	0.095244	99			

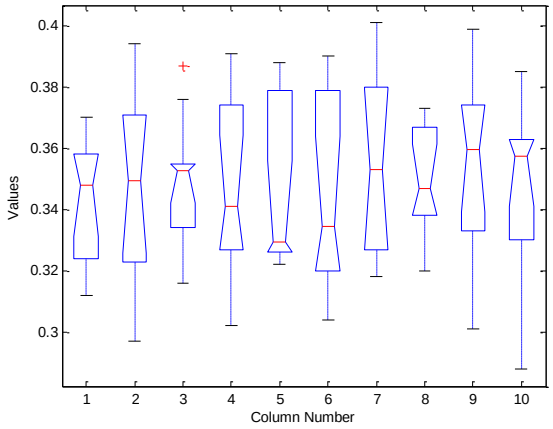

Fig. 5 Box Plot of Upper Left Force Data for Different Test

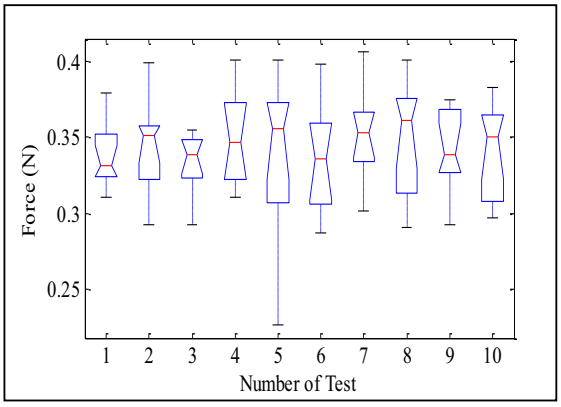

Fig. 6 Box Plot of Lower Left Force Data for Different Test

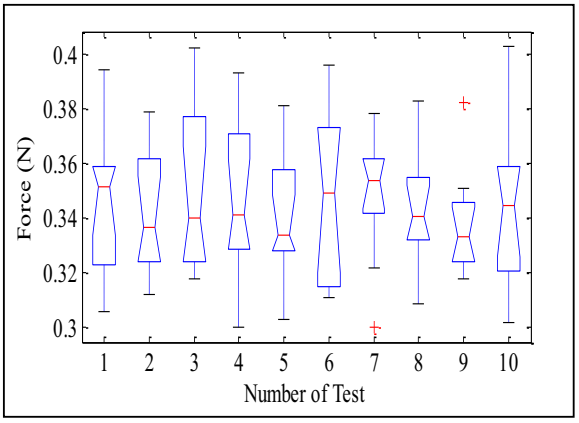

Fig. 7 Box Plot of Upper Right Force Data for Different Test

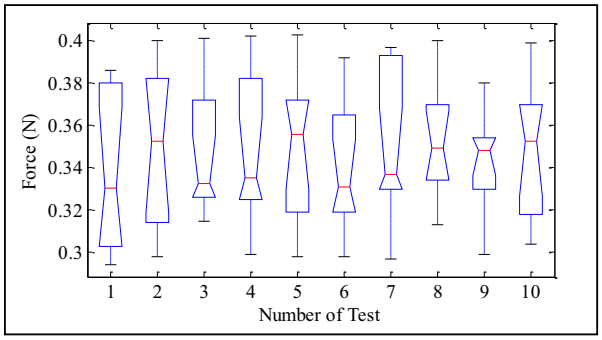

Fig. 8 Box Plot of Lower Right Force Data for Different Test

IV. CONCLUSION

This ARME appliance appears to have a number of advantages over the traditional appliance, the main one being that it can reduce the patient co-operation in RME treatment. The doctor seems more intelligent as it can be programmed to expand the maxilla 2 or 3 times daily.

From the force testing analysis, ANOVA test show that for all the tests, F is much lower than the critical value. It concluded that the force distribution for each tooth was constant during the different time of testing. This result indicates that the ARME appliance can produce a constant force for each relevant tooth over a long period of time.

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