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ARME Appliance: The New Design of Rapid Maxillary Expansion Appliance

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***Abstract* - Expansion of the maxilla is used to correct skeletal and dental transverse discrepancies between the maxilla and mandible. These discrepancies are corrected through a combination of skeletal expansion (separation of the maxillary midpalatal suture) and dental expansion (lateral tipping of the maxillary posterior teeth). The rapid maxillary expansion appliance is a tooth-borne appliance that consists of a midpalatal jackscrew. Appliances currently on the market for expanding the maxillary dentition vary from simple tooth tipping devices to rigid orthopedics expanders. These devices vary widely from active implants with springs and/or screw, to passive acrylic molds and simple medical tape. The problem with current devices is they need to be manipulating manually multiple times to readjust the screw, which requires a considerable time commitment from the family and the physicians. Therefore the goal of this project is to design the new Rapid Maxillary Expansion appliances, namely as Automated Rapid Maxillary Expansion (ARME), which encompasses the benefits of current devices and is easily adjustable.**

***Keywords* – Rapid Maxillary Expansion, automated appliances, micro gear, micro motor, microcontroller**

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 [1-4]. The goal of palatal expansion is to maximize the skeletal movement and to minimize the dental movement [5, 6], while allowing for physiological adjustment of the suture during separation [7, 8].

Expansion appliances can be classified as rapid or slow expander. Rapid maxillary expansion (RME) is an expansion of maxilla accomplished through heavy forces that are capable of separating the midpalatal suture at the rate of 0.2 to 0.5 mm per day, while the slow maxillary expansion is an expansion of maxilla accomplished through light forces that are capable of separating the midpalatal suture at the rate of 0.5 to 1.0 mm per week.

Rapid maxillary expansion produces large forces at the sutural site over a short period of time [6]. These high magnitude forces maximize skeletal separation of midpalatal suture by overwhelming the suture before any dental movement or physiological sutural adjustment can occur [2, 9, 10]. In this technique, the doctor will make/used a custom appliance for the patient which is fixed to the upper molars (Fig.1). Generally the patient/parent will turn this appliance every day for a proscribed number of days as directed by the doctor. The appliance is usually activated on a daily basis by having the patient turn the active part of the screw or spring a prescribed amount.

Fig. 1. RME appliance

This procedure can be done rapidly or slowly depending upon the patient's age and treatment plan. Isaacson and Ingram [6], using a Haas rapid expander, reported that single activations of the jackscrew (0.2mm) produce forces ranging from 3 to 10 pounds and that multiple daily activation can produce forces up to 20 pounds.

After turning is stopped, the appliance may be kept in place for a number of weeks to allow the widening of the jaw to become permanent, the appliance is then removed.

II. BACKGROUND OF THE DESIGN PROBLEM.

The current devices being used all have limitations, including restricted movement, on-universal application and inefficiency. Current devices are inefficiency because it requires many clinical visits to manipulate the orthopedics or to replace jackscrews as shown in Fig. 2.

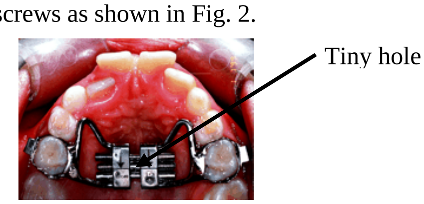


Fig. 2. Butterfly RME appliance

Current expanders turned by placing a pin in a tiny hole (capstan) and pushing that hole with the pin (Fig. 3) inserted to the rear of the expander. Some of the difficulties using the pin driven expanders are that the expander gets stuck midway because the parent/patient does not push far enough back or the hole gets clogged with food and the patient/parent cannot get the pin in to push or turn it.

Fig 3. Butterfly RME pin

Current orthopedics devices share these common features that can be considered as disadvantage to the patient:

- Need to activate manually
  Current devices need the patient/parent to manually activate the screw, which is difficult for the parent to use. If the parent or patient forgot to activate the appliance, it will disrupt the result of treatment.

- Need to keep track of the number of activations.
  Current practice is to ask parents/patient to keep track of the number of activation. Appliances are usually activated daily. This places the responsibility on the parent to remember both to perform the activation and to record the activation.

- Side effect of heavy expansion forces [12].
  Due to this heavy force, pathological effect such as root resorption, alveolar dehiscence and fenestration due to overpower appliances have been reported.

- Maintaining the consistency of the screw turn.
  It is very important to the patient / parent to carefully remove the key without un-turn the screw. If it is happen, the next hole at the front of the screw will be obstructed and the key cannot be inserted for the next activation.

All these difficulties and disadvantage will course disruptive to the orthodontics result. Based on this consideration, it is very important to design and develop the new automated appliance that eliminates the conventional tiny pin and will activating automatically and does not require the regular replacement of screw or other mechanism.

III. ARME APPLIANCES CONSTRUCTION AND DESIGN

To overcome the limitations of conventional expansion appliances, the ARME appliance was designed and developed using a combination of butterfly expander, micro gear and micro motor and also the microcontroller to produce light, continuous pressure on the midpalatal suture as shown in Fig. 4. 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.

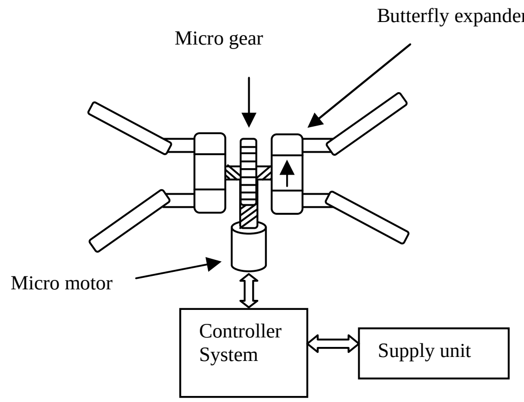


Fig. 4. Schematic diagram of ARME appliance

The design and construction of ARME can be divided into five phases that is (a) preliminary design of automated RME, (b) mechanical modification, (c) microcontroller system design, (d) system integration and (e) Testing. These five phases will be described in the following.

A. First phase – preliminary design of ARME

First phase consists of preliminary design of automated RME system. This includes how to move the expander without using RME pin. In this phase, the type and specification of micro gear, micro motor and microcontroller that used in this system have been decided.

<u>Micro motor</u>

Faulhaber DC micro motor series number 0816S (Fig. 5) was selected in this project due to it size and voltage supplied. Table 1 describes the specification of this motor.

TABLE I
DC MICRO MOTOR SPECIFICATION

Outer Diameter	Length	Shaft Diameter	Norminal Voltage	Output power
6mm	16mm	1.5mm	3..8V	0.18W
No-load speed	Stall torque	Commutation		
17,100	0.41mNm	PM(precious metal)		

The main difference between FAULHABAUR DC-Micro motor and conventional DC motor is in the rotor. The winding does not have an iron core but only consists of a self supporting skew-wound copper coil. This featherweight rotor has an extremely low moment of inertia and it rotates without cogging. The result is the outstanding dynamic of micro motor.

Fig. 5. DC Micro motor

Micro Gear

The diameter of micro gear, d is 9.4 mm and width is 1.53mm. Number of gear teeth is 30.

Microcontroller

In this project, the AT89C2051 microcontroller has been chosen as a controller. This device as shown in Fig. 6 is manufactured by Atmel. This microcontroller is a 20-pin Integrated Circuit (IC). The emphasis is given on 20-pin devices because these twenty-pin devices are very suited when the PCB space available is small, and the need of I/O lines is fulfilled with 15 I/Os. These devices support fully static operation from 0 to 24MHz. The low frequency operation is very important when the power consumption is to be kept minimum. In case of the battery operated instruments, power consumption is crucial. The power down modes and IDLE modes can be used to keep the power consumption to a minimum level. This AT89C2051 device support low-level voltage operation, typically in range 2.7V – 6V.

Fig. 6. Microcontroller AT89C2051.

Butterfly Expender

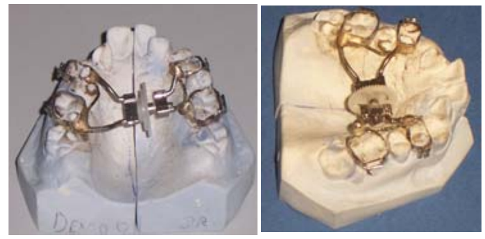
Based on study that have been done, the most frequently used type of Rapid Maxillary Expansion appliance was the Hyrex screw (75%) soldered to bands [11]. Based on this statement, Butterfly expander (Fig. 7) have been choose to modified as a automated rapid maxillary appliance.

Fig. 7. Butterfly RME appliance

B. Second phase – Mechanical Modification

The second phase is mechanical modification of the butterfly expander. Modification is made by replacing the tiny hole section of expander screw with the micro gear. The purpose of this micro gear is to interface with micro motor, and when the micro motor spins it will turn this micro gear to a desired position.

The modified Butterfly expander is then soldered to bands placed on the second primary molar and primary molar as shown in Fig. 8.



(a) Top View (b) Side view

Fig. 8. Modified Butterfly expander with micro gear

C. Third phase – Microcontroller System Design

The third phase in design ARME is to design and build the controller system. The circuit for AT89C2051 microcontroller connection diagram and the minimum hardware environment is shown in Fig. 9. Microcontroller circuit drawing has been done using PCB circuit design. Testing is made to the circuit by writing testing program using assembly language.

Fig. 9. Microcontroller circuit

The next step in this phase is to design, write and testing the assembly language program to run the motor based on the system requirement.

D. Forth phase – System Integration

Fourth phase is system integration. In this phase, all subsystem consists of the controller system, micro motor and the modified butterfly expander have been integrated as a one system. Assembly language will be used as programming code to control the movement of micro motor. Testing has been made to verifying that all components interact as expected and function properly.

E. Fifth phase – Testing

Once the ARME appliance function as expected and properly, laboratory testing of the ARME appliance have been done consists of testing the repentances of dental arch movement and measuring the force applied to the every teeth that was bonded with ARME appliances.

IV. MEASURING FORCE

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 LabView software. Each time the micro motor move to expand the maxilla, the force created by the expander was recorded in the table as shown in Fig. 10.

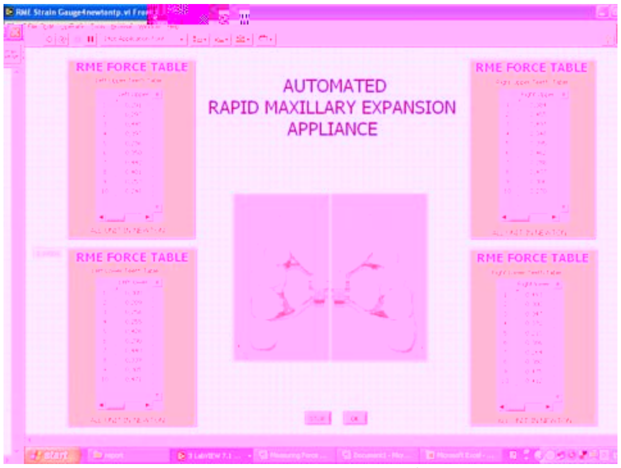


Fig 10. Front Panel to measure force

V. Experimental Result

The forces created by the expander each time the micro motor moves to expand the maxilla for different four teeth are saved and plotted as in Fig. 11 to Fig. 14. 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.

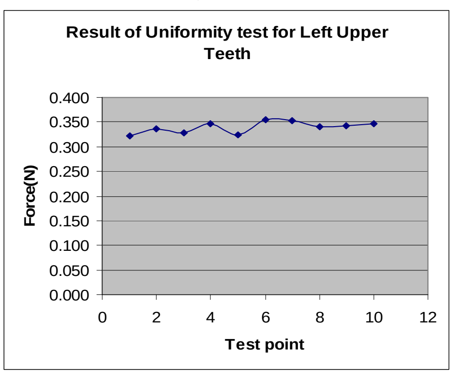


Fig. 11. Force distribution for left upper teeth

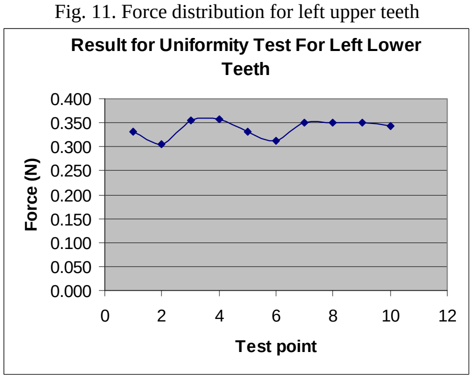


Fig. 12. Force distribution for left lower teeth

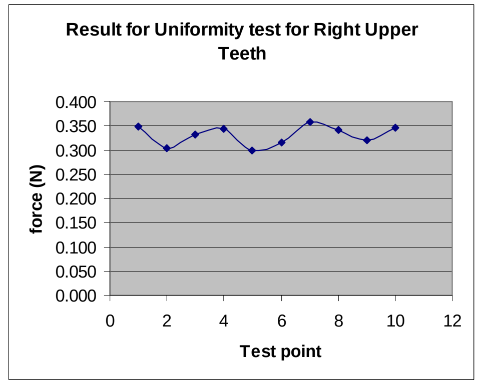


Fig. 13. Force distribution for right upper teeth

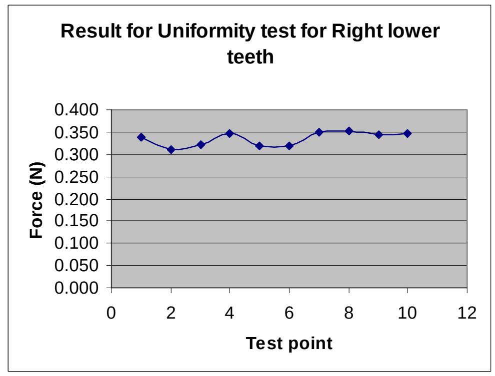


Fig. 14. Force distribution for right lower teeth

VI. 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 was 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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