

Original Article

Development of a Device Prototype for Orthodontic Debonding Force Measurement

Pandurangan Harikrishnan^{1*}, Varadaraju Magesh², Moodur Narayanan Aditya³,
Thoodur Venkatachalapathy Varun³, Vijay Srikrishnan², Rahul Devulapalli²

¹Teeth“N” Jaws Center, Nungambakkam, Chennai 600034, Tamil Nadu, India

²Department of Mechanical Engineering, ³Department of Electronics and Communication Engineering, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Chengalpattu 603203, Tamil Nadu, India

Received: 18 October 2025

Accepted: 25 October 2025

Published online: 28 October 2025

Keywords: *debonding force, orthodontic attachment, orthodontic device, force sensitive resistor, force measurement*

Orthodontic fixed appliance therapy involves rigid attachments like brackets, molar tubes etc. bonded on teeth surface for transferring forces in moving teeth. After the treatment, these attachments are debonded by pliers. The debonding forces leads to pain and discomfort for the patients during the procedure. There are no ways of measuring this force which is uncontrolled and is within the expertise of the clinicians. Our objective was to design a device prototype for measuring the debonding forces. The design consists of Force Sensitive Resistors (FSR) mounted on the debonding plier which is connected to a constructed circuit with a microcontroller. A two-layer Printed Circuit Board (PCB) was fabricated which is connected to the microcontroller and measures the forces applied on the plier handle through an Integrated Development Environment (IDE). A single buccal tube bonded on artificial molar teeth samples were debonded by the clinician author in a horizontal rotating direction which measured the mean debonding force as 6.88 N (688 g). Thus, our prototype design clearly showed the possibility of accurately measuring the debonding forces useful for clinical application and to maintain forces within patient comfort levels.

© (2025) Society for Biomaterials & Artificial Organs #20020025

Introduction

Orthodontic fixed appliance therapy involves rigid attachments like brackets, molar tubes etc. bonded on teeth surface for transferring forces in moving teeth. The bonding agent has enough bond strength to hold the attachments for a period of 2-3 years of fixed appliance treatment. After the treatment, these attachments are removed carefully from the enamel surface by specific orthodontic debonding pliers. In the enamel surface where the tensile, torsion or shear forces are induced, enamel fractures were noticed [1]. A Finite Element (FE) study showed that the debonding method decides the type of enamel failure and further studies were suggested. [2]. To measure the debonding strength of different orthodontic adhesives, the tensile, shear and torsional stresses in the enamel surface were measured [3]. A clinical study suggested that the bracket base geometry is the important factor that caused discomfort to the patients during debonding [4].

In a review paper, authors concluded that application of finger pressure, biting of wafer and pain reducing medicines can be used to reduce the intensity of debonding pain [5]. The transcutaneous electrical nerve stimulation method helped to reduce the pain during debonding. The pain level in female patients was more and pain in maxillary anterior teeth was less compared to mandible anterior teeth [6]. Traditional bracket removal plier showed reduced debonding pain compared to the third wedging arm Damon clear debonding plier. This study suggested that further studies are required to know the other factors causing the pain and discomfort to patients which needs to be minimized [7]. A device was developed, measuring the debonding force using Lift-off Debonding Instrument (LODI, 3M Unitek, USA) along with enamel damage suggested that bonding strength of the brackets varied between teeth [8].

A debonding force measurement device was developed to measure the debonding force of the bracket using one FSR. In this study, only the thumb finger force was measured by placing the device in a fixed position during debonding [9]. Debonding force of brackets in male and female subjects were measured using a

* Corresponding author

E-mail address: teethnjaws01@gmail.com (Dr. Pandurangan Harikrishnan, Craniofacial Orthodontist, Teeth“N” Jaws Center, Nungambakkam, Chennai 600034, Tamil Nadu, India)

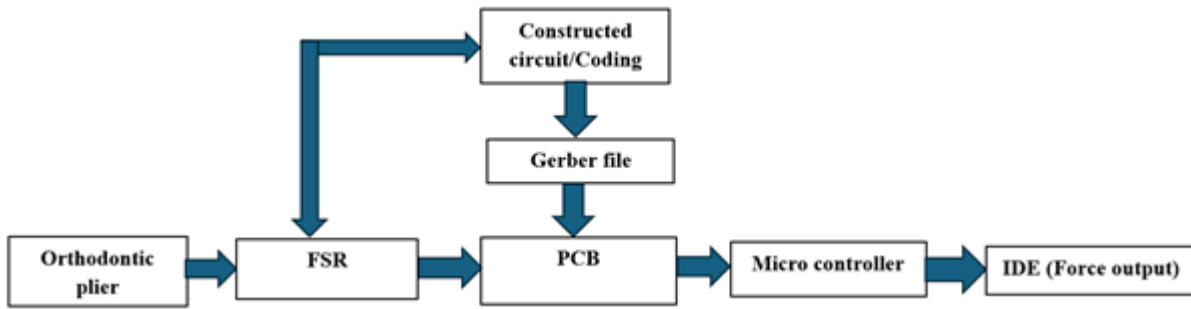


Figure 1: Design methodology of orthodontic debonding force measurement device

developed device. In this study, the debonding plier design was modified to place the cylindrical load cell by adding additional grip and concluded that the pain was higher in the maxillary and mandible anterior segment [10]. An experimental study using strain gauges bonded pliers to measure the debonding force suggested that the debonding force depends on the direction and method of debonding [11]. A strain gauge was used by modifying the plier design to measure the debonding force in an *in vivo* study [12]. Different pliers were used to assess the patient discomfort during debonding and concluded that the pain and discomfort level is higher when a straight cutter plier was used [13].

As mentioned, few *in vitro* and *in vivo* studies were available to measure the debonding force with the attachment of sensors. But, those studies involved measuring the force applied by one finger with a fixed position or with extensive plier modification. Thus, the objective of our study was to design and develop a device to measure the debonding force without altering the plier design and holding them similar to clinical debonding procedures.

Materials and Methods

The design methodology used to develop the orthodontic debonding force measurement device is shown in figure 1. The device comprises of an orthodontic Straight Howe plier, 5.08 mm diameter FSRs (Techtonics, India) shown in figure 2a, a two-layer PCB (figure 2b), microcontroller – Mega 2560 R3, China SKU, China (figure 2c) and an Integrated Development Environment (IDE) software for the force output measurement. In this study, five FSRs were fixed on the plier handle to cover all the fingers and palm contact points on the handle as shown in figures 2c and d. The FSRs are configured to detect and measure applied real-time multi-directional forces. From the constructed circuit, coding was developed in IDE. The coding was converted into a Gerber file to print the two-layer PCB. The PCB was mounted on the microcontroller to link the constructed circuits. One end of the Jumper wire was used to connect to the FSRs, and another end is with PCB which was mounted on microcontroller as shown in figure 2c.

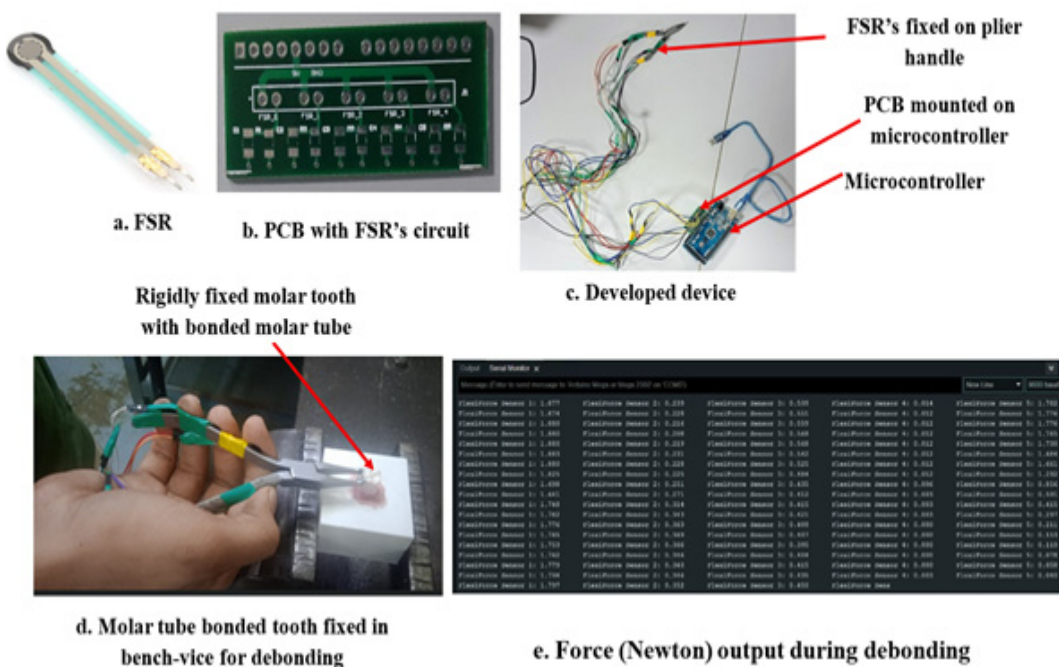


Figure 2: Components and working of orthodontic debonding force measurement device

Artificial molar tooth was placed in square PMMA resin block as shown in figure 2d. A single buccal tube was bonded on the molar buccal enamel surface using bonding agent (Transbond XT, 3M Unitek, USA) and light cured as per regular clinical protocol. Six such samples were prepared and were placed in an incubator for 24 hours simulating the oral environment with 37°C with 80% humidity. The samples were fixed in a bench-vice and the developed sensor mounted plier was used to hold the buccal tube mesio-distally in a horizontal direction (figure 2d) and force was applied with rotating motion on the molar tube for debonding. The plier applied debonding forces were captured through the IDE for all the five FSRs as shown in figure 2e and recorded.

Results and Discussion

The developed orthodontic debonding force measurement device was tested to verify its functionality. For the testing purpose, a horizontal rotary direction debonding force was applied on the single buccal tube bonded on the molar tooth as shown in figure 2d. This method of force application is clinically common and thus used in our device testing. Using five FSRs, the measured horizontal direction debonding force values in the tested six samples were 687 g, 672 g, 695 g, 680 g, 702 g and 692 g. The mean force of the six samples was 688 g (6.88 N).

Few studies used LODI with one FSR to measure the debonding force of orthodontic brackets [8,9]. Currently, the LODI is not available for clinical use as the instrument itself has been out of manufacture for a decade now. They used only one FSR to measure the applied thumb finger force on the upper part of the instrument. One FSR and one finger only cannot capture the exact debonding force. Our device was designed using Five FSRs to cover all the contact areas from the fingers and the palm on the plier handle. In a study, the debonding plier design was modified to insert a load cell by adding additional grip with one of the plier handles [10]. It is technically difficult to include a load cell or sensor in the plier by modifying its design which itself will affect the clinical way of using the plier.

In our device we can bond the FSRs using any thin bonding tape on the plier handle contact areas and it is easy to use without modifying the plier design. Studies used strain gauges with polypropylene pliers, measured the debonding force through the deformation of the plier arm [11]. In their study, holes are made in the lateral surface of the active arm in the plier and metal coatings were applied on the plier to bond the strain gauges. Also, a silicon layer without acetic acid was applied surrounding the strain gauge. FSRs are inexpensive, flexible, thin and easy to interface with microcontrollers with fast response. So, in our study we have used FSRs in appropriate shape and size to adapt to the plier handle.

Our device does not require any extensive procedures to measure the debonding force. In our design, a precise bonding of FSRs is required due to the curvature in the top surface of the plier handle. If the FSR slips from the curved handle, it cannot measure the forces accurately which is a limitation in our design. In future, minimizing the number of FSRs, hand movement measurement along with Bluetooth IoT facility can be included. Further *in vitro* and *in vivo* studies are required for the effective testing and utilization of the device which is our ongoing work. Clinically, the device

prototype is useful to measure the orthodontic debonding forces by orthodontists and helpful to know the force levels which can cause discomfort to the patients.

Conclusion

An innovative design was used to develop a debonding force measurement device, and its functionality was verified. The device does not require any alteration in the plier design and is suitable for any plier for *in vivo* and *in vitro* debonding force measurement. Thus, our prototype design clearly showed the possibility of accurately measuring the debonding forces useful for clinical application and to maintain forces within patient comfort levels.

Acknowledgement

This work was funded by the Department of Science and Technology – Anusandhan National Research Foundation (erstwhile SERB) (CRG/2022/005834) Government of India. The device prototype is applied for IPR (Indian patent application number : 202541041047).

References

1. Chen-Sheng Chen, Ming-Lun Hsu, Kin-Di Chang et al., Failure analysis: Enamel fracture after debonding orthodontic brackets, *Angle Orthod.* 78(6), 1071-1077 (2008).
2. Holberg C, Winterhalder P, Holberg N, et al., Orthodontic bracket debonding: risk of enamel fracture, *Clin Oral Investig.* 18(1), 327-34 (2014).
3. Valletta R, Prisco D, De Santis R, et al., Evaluation of the debonding strength of orthodontic brackets using three different bonding systems, *Eur J Orthod.* 29(6), 571-577 (2007).
4. Gibas-Stanek M, Fudalej P. Does the pain experienced during orthodontic treatment and bracket removal depend on the architecture of the bracket or debonding method?, *Eur J Orthod.* 47(1), cjae073 (2024), Erratum in: *Eur J Orthod.* 47(2), cjaf016 (2025).
5. Bahaa Aldeen Jeha, Rania Haddad. What is the most effective method for reducing pain during debonding procedures? A systematic review, *Int Orthod.* 23(2) (2025).
6. Rastogi A, Sharma P, Ram CS, et al., Evaluation of Pain Perception During Orthodontic Debonding of Metallic Brackets with Simultaneous Application of TENS Therapy, *Turk J Orthod.* 37(1), 50-55 (2024).
7. Smaysim, Hasanain L, Nissan, Layth MK. Clinical Assessment of Pain Levels and Debonding Forces Using the Damon Clear Debonding Plier: A Split-Mouth, Controlled Clinical Trial, *Dent. Hypotheses.* 16(1), 1-3 (2025).
8. Tamzid Ahmed, Norma Ab Rahman et al., Comparison of Orthodontic Bracket Debonding Force and Bracket Failure Pattern on Different Teeth In Vivo by a Prototype Debonding Device, *Biomed Res Int.* 2021, 6663683 (2021).
9. Tamzid Ahmed, Norma Ab Rahman, Mohammad Khursheed Alam. Validation and reliability of a prototype orthodontic bracket debonding device equipped with force-sensitive resistor (FSR): a novel method of measuring orthodontic bracket debonding force in vivo, *Prog Orthod.* 20, 26 (2019).
10. Narumi N, Yasuki U, Mizuki I et al., Pain and removal force associated with bracket debonding: a clinical study, *J Appl Oral Sci.* 29, 1-9 (2021).
11. Prietsch JR, Ana Maria S, Isaac Newton LDS et al., Development of a device to measure bracket debonding force *in vivo*, *Eur. J. Orthod.* 29(6), 564–570 (2007).
12. Tonus JL, Manfroi FB, Borges GA et al., Prototype to measure bracket debonding force in vivo, *Dental Press J Orthod.* 22(1), 82-88 (2017).
13. Pithon MM, Daniel Santos FF, Dauro Douglas O et al., What is the best method for debonding metallic brackets from the patient's perspective?, *Prog Orthod.* 16, 17 (2015).