IFMBE Proceedings

James Goh · Chwee Teck Lim (Eds.)

Volume 52

7th WACBE World Congress on Bioengineering 2015

6th to 8th July, 2015, Singapore

Springer

James Goh · Chwee Teck Lim
Editors

7th WACBE World Congress on Bioengineering 2015

6th to 8th July, 2015, Singapore

Springer

IFMBE Proceedings

Volume 52

Preface

On behalf of the Organizing Committee of the WACBE World Congress on Bioengineering 2015 (WACBE 2015), we would like to warmly welcome you to this meeting. This congress is part of a series that began in 2002 and we had six meetings thus far. This year's meeting is jointly organized by the Department of Biomedical Engineering of the National University of Singapore (NUS) and the Biomedical Engineering Society (Singapore) (BES). This congress is also endorsed by the International Federation for Medical and Biological Engineering (IFMBE).

We are glad to report that we have more than 200 participants from 17 countries. In this congress, we have received close to 300 abstracts with 50 being keynote/invited presentations. The rest of the contributed abstracts were peer-reviewed, with 124 accepted for oral and 99 accepted for poster presentations. Out of these accepted abstracts, we received 55 final papers submitted for the proceedings, with 2 being invited papers, 25 oral presentation papers and 28 Poster papers.

We are very honoured to have Prof Kam Leong as the inaugural Savio Woo Distinguished Lecturer, as well as other very prominent speakers as our Plenary and Keynote Speakers. Each of these speakers is an authority in their field of research and we are grateful that they are able to participate in this congress.

We do know that the success of a congress lies in the participation of the delegates and the quality of papers presented. Nevertheless, we also know that this will not be possible without the help and effort put in by the volunteers, reviewers, as well as the members of the Organizing Committee, Scientific Committee and the International Advisory Committee. Their dedicated contributions to this meeting are very much acknowledged and appreciated. We would also like to sincerely thank our sponsors, supporters and exhibitors for contributing to the success of this congress.

Finally, we would like to thank the staff of INMEET CMS Pte Ltd who has ensured the smooth running of the congress. Finally, to all our delegates, I hope this WACBE 2015 meeting will not only be one where excellent scientific ideas are exchanged and shared, but also friendships are renewed and new friends made. Do enjoy the congress as well as the sights and sounds of Singapore!

Best wishes

Prof James Goh
Chairman

Prof Chwee Teck LIM
Scientific Program Chair

WACBE 2015 Organizing Committee

The International Federation for Medical and Biological Engineering, IFMBE, is a federation of national and transnational organizations representing internationally the interests of medical and biological engineering and sciences. The IFMBE is a non-profit organization fostering the creation, dissemination and application of medical and biological engineering knowledge and the management of technology for improved health and quality of life. Its activities include participation in the formulation of public policy and the dissemination of information through publications and forums. Within the field of medical, clinical, and biological engineering, IFMBE's aims are to encourage research and the application of knowledge, and to disseminate information and promote collaboration. The objectives of the IFMBE are scientific, technological, literary, and educational.

The IFMBE is a WHO accredited NGO covering the full range of biomedical and clinical engineering, healthcare, healthcare technology and management. It is representing through its 60 member societies some 120.000 professionals involved in the various issues of improved health and health care delivery.

More information about this series at http://www.springer.com/series/7403

Editors
James Goh
Faculty of Engineering
National University of Singapore
Singapore

Chwee Teck Lim
National University of Singapore
Singapore

ISSN 1680-0737 ISSN 1433-9277 (electronic)
IFMBE Proceedings
ISBN 978-3-319-19451-6 ISBN978-3-319-19452-3 (eBook)
DOI 10.1007/978-3-319-19452-3

Library of Congress Control Number: 2015941131

Springer Cham Heidelberg New York Dordrecht London

The IFMBE Proceedings is an Official Publication of the International Federation for Medical and Biological Engineering (IFMBE)

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Committees

Organising Committee

Chairman

Goh James	National University of Singapore, Singapore

Vice Chair

Toh Siew Lok	National University of Singapore, Singapore

Secretary

Lim Sierin	Nanyang Technological University, Singapore

Treasurer

Buist Martin	National University of Singapore, Singapore

International Advisory Committee Chair

Chew Yong Tian	National University of Singapore, Singapore

Scientific Programme Chair

Lim Chwee Teck	National University of Singapore, Singapore

Scientific Programme Co-Chair

Zhang Yong	National University of Singapore, Singapore

International Advisory Committee

Members

An, Kai-Nan	Mayo Clinic, USA
Cheng, Cheng-Kung	National Yang Ming University, Taiwan
Cheng, Dong	Penn State University, USA
Chien, Shu	University of California, San Diego, USA
Fan, Yubo	Beihang University, China
Guo, Edward	Columbia University, USA
Hsing, I-Ming	The Hong Kong University of Science and Technology, Hong Kong
Ji, Baohua	Beijing Institute of Technology, China
King, Albert	Wayne State University, USA
Lee, Abraham	University of California, Irvine, USA
Lee, Peter Vee Sin	The University of Melboume, Australia
Leong, Kam W.	Columbia University, USA
Li, Guoan	Massachusetts General Hospital / Harvard Medical School, USA
Li, Zong-Ming	Cleveland Clinic, USA

Lin, Feng-Huei	National Taiwan University, Taiwan
Lin, Kang-Ping	Chung Yuan Christian University, Taiwan
Lu, Helen	Columbia University, USA
Lu, William	The University of Hong Kong, Hong Kong
Mak, Arthur FT	The Chinese University of Hong Kong, Hong Kong
Ning, Gangmin	Zhejiang University, China
Ouyang, Hongwei	Zhejiang University, China
Phee, Louis	Nanyang Technological University, Singapore
Su, Fong-Chin	National Cheng Kung University, Taiwan
Sung, Hsing-Wen	National Tsing-Hua University, Taiwan
Teoh, Swee Hin	Nanyang Technological University, Singapore
Wang, Jawlin	National Taiwan University, Taiwan
Wu, Benjamin	University of California, Los Angeles, USA
Yang, Changhuei	California Institute of Technology, USA
Zhang Fan	Fudan University, China
Zhang Ming	The Hong Kong Polytechnic University, Hong Kong

Scientific Program Committee

Chair

Lim Chwee Teck	National University of Singapore, Singapore

Co-Chair

Zhang Yong	National University of Singapore, Singapore

Members

Li Jun	National University of Singapore, Singapore
Leo Hwa Liang	National University of Singapore, Singapore
Chen Chia Hung	National University of Singapore, Singapore
Chen Nanguang	National University of Singapore, Singapore
Alberto Corrias	National University of Singapore, Singapore
Huang Zhiwei	National University of Singapore, Singapore
Kah Chen Yong James	National University of Singapore, Singapore
Kanchanawong Pakorn Tony	National University of Singapore, Singapore
Tan Kian Lee	National University of Singapore, Singapore
Yu Haoyong	National University of Singapore, Singapore
Ren Hongliang	National University of Singapore, Singapore
Mrinal Kanti Musib	National University of Singapore, Singapore
Toh Siew Lok	National University of Singapore, Singapore
Yen Shih Cheng	National University of Singapore, Singapore
Yim Evelyn	National University of Singapore, Singapore

A Study of Frictional and Biomechanical Forces in a Trapezoidal Bracket versus Rectangular Bracket and Periostin Activity

Teresa Cobo[1], Alberto A. Suárez[2], Juan Cobo[1], Santiago Cal[3], and Álvaro J. Obaya[4]

[1] Department of Surgery and Medical-Surgical Specialties, University of Oviedo and Instituto Asturiano de Odontología. Asturias. España
[2] Department of Mechanical Engineering. Escuela Politécnica Superior de Ingeniería. University of Oviedo. Asturias. España
[3] Department of Biochemistry and Molecular Biology. University of Oviedo. Asturias. España
[4] Department of Fuctional Biology. University of Oviedo. Asturias. España

***Abstract* – This paper presents a study of the frictional and biomechanical forces in a trapezoidal versus rectangular bracket. The main aim is to validate the novel and innovative bracket design (utility model U-2013 30 854 applied for on: 8th July 2013. The scope of protection of this utility model covers Spain, France and Portugal).**

Keywords - **orthodontics, trapezoidal bracket, biomechanical, periostin.**

I. Introduction

Orthodontic treatment is characterized by the application of forces to teeth with the intention of moving them to a predetermined desired position. To efficiently establish tooth movement, the forces applied to the teeth mist be within a certain range. Forces which are too high can result in rapid, painful tooth movement or ankyloses, while forces are too low can result in slow or non-existent tooth movement.

Our hypothesis is the following: given that the archwire is not only supported by the bottom of the slot, but also by the walls, could a change in the morphology of the slot and/or archwire achieve an improvement in the behavioural relationship between the two in different scenarios? At first the bracket had a standard, rectangular face, and now, why not a trapezoidal face?

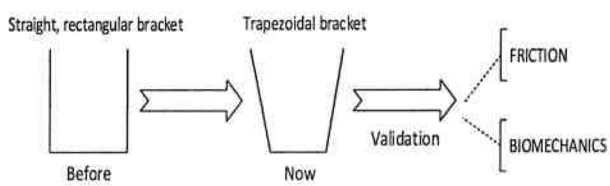

Fig. 1 Evolution of the bracket

II. Method

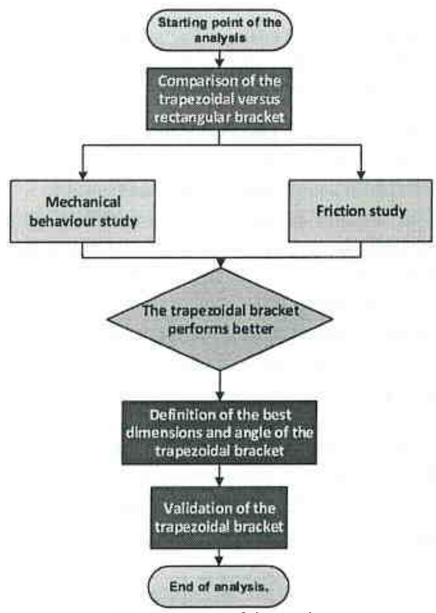

Fig. 2 Stages of the study

A. Study of the Mechanical Behaviour of a Trapezoidal versus Rectangular Bracket

A numerical simulation was performed using the 3D finite element method of three models of a dental bracket with different geometries for the cross-section of the archwire/slot: one "rectangular" in shape; one with trapezoidal geometry, $\alpha = 5°$ in the area of interest; and a third with trapezoidal geometry, $\alpha = 8°$.

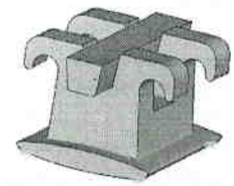

Fig. 3 Trapezoidal bracket

J. Goh and C.T. Lim (eds.), *7th World Congress on Bioengineering 2015*
IFMBE Proceedings 52, DOI: 10.1007/978-3-319-19452-3_22

B. COMPARATIVE STUDY OF ARCHWIRE FRICTION ON DIFFERENT BRACKET GEOMETRIES. 1st CASE

Three case studies were conducted of the bracket/archwire assembly, varying its geometry.

-Rectangular bracket with rectangular archwire.

-Trapezoidal bracket with rectangular archwire.

-Trapezoidal bracket with rectangular archwire supported on one side.

To obtain comparable results, all cases were simulated under the same conditions of friction, estimating a single coefficient of dynamic friction. Similarly, the forces applied to the archwire were always equal and constant for all studies, the estimated slip velocity between the bracket and archwire taking an equal and constant value in all cases.

C. COMPARATIVE STUDY OF ARCHWIRE FRICTION ON DIFFERENT BRACKET GEOMETRIES – VARYING THE ANGLE OF THE TRAPEZOIDAL SLOT BETWEEN 1° AND 10°. 2nd CASE

Considering a common state of loading, a statics study of the archwire-bracket system was conducted on 4 possible hypotheses of impending movement.

Ten bracket geometries were studied in each of the four analysed cases, with the angle of the trapezoidal slot taking the values 1°, 2°, 3°... up to 10°.

After defining the relative position between archwire and bracket, different scenarios may be postulated based on hypotheses regarding the possible impending movement the archwire may suffer within the slot.

Specific reactions or frictional forces are generated for each case in each of these scenarios.

Four different cases were postulated, analysing in each one the 10 bracket geometries under study (trapezoidal slot angle varying between 1° and 10°). These cases are described below.

1. The archwire is supported on one wall of the bracket slot, considering no state of impending movement. Hence, no frictional forces appear along the direction of the contact faces.
2. The archwire is supported on one wall of the bracket slot, considering a state of impending movement to exist on this surface. Hence, a frictional force appears along the direction of the slot wall.
3. The archwire is supported on the wall of the bracket slot, considering a state of impending movement to exist on the base of the slot (the archwire tends to be displaced in an anti-clockwise direction. In this case, a frictional force appears along the direction of the base.
4. The archwire is supported on the wall of the bracket slot, considering a state of impending movement to exist simultaneously on the base and the slot wall (the archwire tends to turn in a clockwise direction. In this case, frictional forces appear along the direction of both the base and the contact slot wall.

III. RESULTS

A. RESULTS OF THE STUDY OF THE MECHANICAL BEHAVIOUR OF A TRAPEZOIDAL VERSUS RECTANGULAR BRACKET

RESULTS		
	Max. Stress (Pa)	Max. Displacement (mm)
Straight Bracket	11864806	1,55076 E-07
Trapez. Bracket 5°	11872979	1,59855 E-07
Trapez. Bracket 8°	11884190	1,63252 E-07

Fig. 4 Results of the study

It may be concluded that the geometry of the archwire in the states of loading torque and compressive force:

1. Has a local effect only in terms of the distribution of forces around the slot.
2. The distribution of forces in the base of the bracket is independent of the local geometry of the archwire and the slot.
3. The actions or forces transmitted to the tooth are independent of the local geometry of the archwire and the slot.

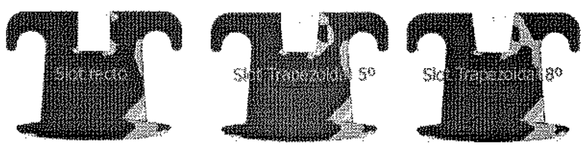

Fig. 5 Comparison of the 3 cases

B. RESULTS OF THE COMPARATIVE STUDY OF ARCHWIRE FRICTION ON DIFFERENT BRACKET GEOMETRIES. 1st CASE

RESULTS	
	Frictional force [N]
Rectangular bracket with rectangular archwire	4.9504
Trapezoidal bracket with trapezoidal archwire	4.9068
Trapezoidal bracket with rectangular archwire supported on slot wall	3.5005

Fig. 6 Results of the comparative study

As can be seen from the above table, the results of the frictional forces vary considerably depending on the loading case. Although the value of the applied forces is the same in all cases, the geometry of the bodies on which they are applied varies, resulting in a variation in the normal components associated with these external forces.

From these results, it can be concluded that:

Brackets with rectangular slots generate greater frictional forces than those with a trapezoidal geometry.

For small angles of the trapezoidal slot (between 0.1°-1°), the influence on the resulting frictional force is very small, as this depends directly on its cosine component.

In the case of rotation of the archwire relative to the bracket, we assume that contact occurs on a single surface. The component of the reaction force, perpendicular to the surface, is clearly smaller than the sum of the normal components applied to both faces. The frictional force associated with the former normal component will therefore also be less than in the case of contact with two surfaces. Comparing the "trapezoidal bracket/trapezoidal archwire" with the "trapezoidal bracket/rectangular archwire on the slot wall", a decrease of 29% is observed when only one contact surface is involved instead of two.

C. RESULTS OF THE COMPARATIVE STUDY OF ARCHWIRE FRICTION ON DIFFERENT BRACKET GEOMETRIES – VARYING THE TRAPEZOIDAL SLOT ANGLE BETWEEN 1° AND 10°. 2nd CASE

For all hypotheses of movement studied here, it can be concluded that the frictional force always decreases with increasing angle of the trapezoidal slot.

In term of the different postulated cases, the lowest frictional force is found in the archwire that slides along the slot wall until it is supported on its base, without the possibility of it sliding on the latter.

Due to the large number of variables involved in the movement of the archwire inside the bracket, it cannot be affirmed that the same case of impending movement always occurs. That is, the 4 cases of impending movement are not exclusive and, at any one time, one and/or another may occur.

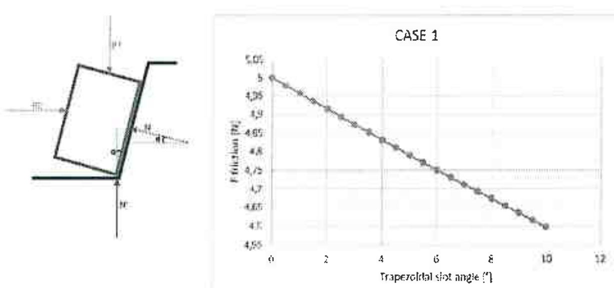

Fig. 7 Results of Case 1

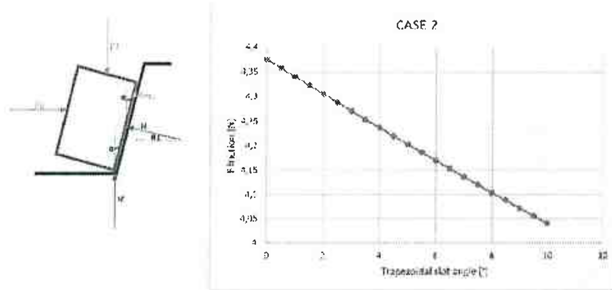

Fig. 8 Results of Case 2

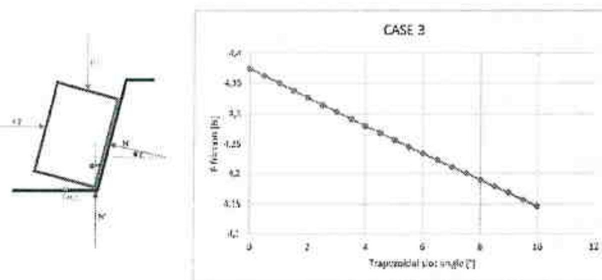

Fig. 9 Results of Case 3

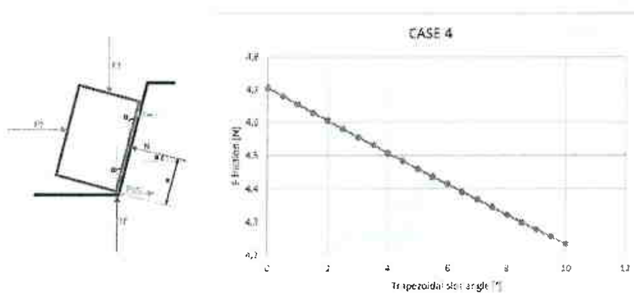

Fig. 10 Results of Case 4

Carrying out a percentage comparison, the most notable decrease in frictional force is produced in the case of the archwire that slides on the slot wall until it is supported on its base, without the possibility of sliding on the latter. This decrease was calculated with respect to the value of the theoretical frictional force (5N), which would be the value in the case of a rectangular bracket and rectangular archwire.

If a torque is produced in the archwire, what is most likely to occur (failing a study to verify this) is that the increasing angle would constitute an adverse factor hindering the rotation of the tooth.

If the direction or sign of the assumed forces are varied (once again failing a study to verify this), increasing the angle of the bracket slot could be counterproductive.

IV. Conclusions

The distribution of forces transmitted to the tooth is more uniform in the trapezoidal than in the rectangular bracket.

Brackets with rectangular slots generate higher frictional forces than those with a trapezoidal geometry.

The frictional force always decreases with increasing angle of the trapezoidal slot.

The lowest frictional force is produced when the archwire slides along the slot wall until it is supported on its base, without the possibility of sliding on the latter.

The study of the frictional forces between the bracket and archwire show that a greater bracket angle (regardless of the assumed hypothesis) produces a decrease in the frictional force of advancement in both the rectangular and trapezoidal archwire.

The maximum recommended angle to manufacture brackets is 8º.

All the preceding results lead us to conclude that the best combination is the trapezoidal bracket with a trapezoidal archwire.

Furthermore, our research provides new evidence on the impact of periostin in the physiology of tooth movement resulting from the application of orthodontic forces using an archwire bracket device with rectangular and trapezoidal slot walls.

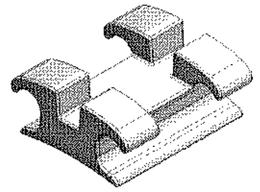

Fig. 11 Design of the innovative trapezoidal bracket

Fig. 12 Comparison of the change in dimensions of the trapezoidal versus conventional bracket

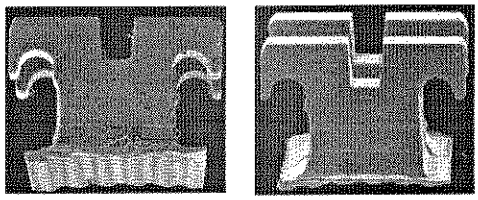

Fig.13 Surface topography of the bracket using a scanning electron microscope.

Acknowledgment

This research was supported by Instituto Asturiano de Odontología, Principado de Asturias, Spain.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

1. Justin K Wong, Dan L Romanyk, Roger W Toogood, Giseon Heo, Jason P Carey and Paul W Major. (2014). The effect of perturbations on resistance to sliding in second-order moments comparing two different bracket types. J Dent Biomech. 5, 1-8.
2. Maria Regina Guerra MONTEIRO, Licinio Esmeraldo da SILVA, Carlos Nelson ELIAS, Oswaldo de Vasconcellos VILELLA. (2014). Frictional resistance of self-ligating versus conventional brackets in different bracketarchwire-angle combinations. J Appl Oral Sci. 22(3), 228-34.
3. Yumi Yanasea, Hideki Loib, Masato Nishiokaa, Ichiro Takahashi. (2014). Effects of sliding velocity on friction. An in vitro study at extremely low sliding velocity approximating orthodontic tooth movement. Angle Orthodontist. 84 (3), 451-458.
4. Raissa Costa Araujoa; Livia Monteiro Bicharab; Adriana Monteiro de Araujob; David Normando. (2014). Debris and friction of self-ligating and conventional orthodontic brackets after clinical use Angle Orthodontist. DOI: 10.2319/012914-80.1.
5. Jun-ya Tominaga, Hiroya Ozaki, Pao-Chang Chiang, Mayumi Sumi, Motohiro Tanaka, Yoshiyuki Koga, Christoph Bourauel, Noriaki Yoshida. (2014). Effect of bracket slot and archwire dimensions on anterior tooth movement during space closure in sliding mechanics: A 3-dimensional finite element study. American Journal of Orthodontics and Dentofacial Orthopedics. vol.146, no.2, Pág.166-174.

Author: Teresa Cobo Díaz
Institute: Department of Surgery and Medical-Surgical Specialties. University of Oviedo, Spain
Email: teresa@iaodontologia.es

Author: Alberto A. Suárez
Institute: Department of Mechanical Engineering. Escuela Politécnica de Ingeniería de Gijón, Spain
Email: suarez@uniovi.es

Author: Juan M. Cobo Plana
Institute: Department of Surgery and Medical-Surgical Specialties. University of Oviedo, Spain
Email: jcobo@uniovi.es