British Journal of Orthodontics/Vol. 25/1998/187–190

Toothbrushing Forces in Children with Fixed Orthodontic Appliances

P. A. HEASMAN, M.D.S., PH.D., F.D.S., R.C.P.S., D.R.D.

I. D. M. MACGREGOR, B.D.S., PH.D., F.D.S.

Z. WILSON, E. D. H.

Department of Dentistry, University of Newcastle upon Tyne NE2 4BW, UK

P. J. KELLY, PH.D.

Centre for Health and Medical Research, University of Teesside, Middlesborough TS1 3BA, UK

Abstract. *The aim of this investigation was to determine whether toothbrushing forces are influenced by wearing fixed orthodontic appliances. Thirty children, (10 males, 20 females) with planned fixed appliance therapy and aged 10–15 years, were recruited to the study. No subject had previously worn an orthodontic appliance. At baseline, each subject brushed their teeth in their usual way, unsupervised. The toothbrush used was a purpose-designed electronic instrument that measured the force applied to the brush and transmitted force data by radio to a remote PC. After toothbrushing, subjects had orthodontic brackets fitted. Toothbrushing was repeated at 2 and 14 weeks after baseline, and brushing forces recorded. There were no significant differences between the measurements made at baseline and those made at 2 and 14 weeks. There were no differences between males and females in the forces used at any time point. It was concluded that toothbrushing forces are unaffected by placing fixed orthodontic appliances in children. The brushing forces recorded were comparable with those previously found by other investigators.*

Index words: Behaviour, Children, Orthodontic Appliances, Toothbrushing.

Introduction

Toothbrushing is the single most important measure used by the public at large for preventing periodontal diseases. People that brush their teeth frequently have less gingivitis and less periodontal pocketing than those that brush less frequently or only occasionally (Addy *et al.*, 1990). Regular and frequent toothbrushing using a dentifrice incorporating fluoride is also recommended for the prevention of dental caries (Sutcliffe, 1989). Orthodontic appliances compromise oral hygiene practices even in the most motivated patient, with consequent plaque retention sufficient to induce the development of gingival inflammation and decalcification.

The extent to which orthodontic appliances alter toothbrushing performance, particularly with respect to the pressures applied with the brush around brackets adjacent to the gingivae, is not known. White (1983) and White and Hobbs (1984) showed that in patients wearing fixed appliances 'good brushers' used significantly greater brushing pressures than 'poor brushers'. Moreover, those subjects with poor oral hygiene reduced their plaque scores by 50 per cent when they increased their brushing pressure (White and Hobbs, 1984). Instruction should emphasise the need to use sufficient pressure to remove plaque; a pressure sensitive toothbrush would be a valuable aid to patients undergoing orthodontic treatment.

There is increasing interest in monitoring the forces applied during toothbrushing. Recent commercial toothbrushes, both manual (Alert, Bioware Inc., Bala Cynwyd, PA, USA) and powered (Dental Logic HP550/510 Philips, Eindhoven, The Netherlands), have incorporated pressure-sensitive devices to warn the user when excessive pressure is being applied. As yet these critical forces are only empirical although the risk of gingival trauma appears to increase with forces above 250 g (unpublished data). Previous attempts to measure toothbrushing forces *in vivo* were hampered by cumbersome apparatus attached to the toothbrush, and hard wiring to the recording apparatus, that made manipulation of the brush in the mouth difficult. However, these studies did establish that toothbrushing forces vary widely between individuals and in different parts of the mouth in the same individual (Heath and Wilson, 1974), with the brushing stroke used (Bjorn and Lindhe, 1966), and with the calibre, arrangement, and length of the brush-head bristles (Fraleigh *et al*., 1967). Using similar technology (strain guages glued to the stem of a toothbrush hard wired to recording apparatus), Van der Weijden *et al*., (1996) reported that greater pressures were used with manual toothbrushes than with electric toothbrushes. These authors also demonstrated that increasing the brushing force removed more plaque when toothbrushing was performed by a dental hygienist at different pre-set brushing pressures.

The purpose of the present study was to determine whether toothbrushing forces in children are influenced by wearing fixed orthodontic appliances, using a recently developed wire-free electronic manual toothbrush (Allen *et al*., 1996) to measure absolute pressures applied to the head of the brush.

0301-228X/98/003000+00$02.00

Materials and methods

Design

As part of a wider investigation of the efficacy of electric toothbrushes in plaque removal in orthodontic patients, 30 children, aged 10–15 years, having a minimum of 20 teeth, and uninstructed in oral hygiene, were recruited to the study with parental consent. Orthodontic treatment with fixed appliance therapy was planned for all subjects. None had received orthodontic treatment previously. At baseline, each subject was asked to brush their teeth in their usual way, in their own time, using a purpose-designed manual force-sensing toothbrush (Allen *et al.*, 1996) and a standard fluoride dentifrice. Toothbrushing was unsupervised. While subjects brushed their teeth, the forces they applied to the brush head were recorded. After toothbrushing, orthodontic brackets and/or bands were fitted to upper and lower arches, for commencement of fixed appliance therapy. At 2 and 14 weeks after baseline all subjects brushed their teeth as before and brushing forces were recorded. The investigation was approved by the Newcastle and North Tyneside Ethics Committee and undertaken according to European Directives for Good Clinical Practice.

Measurement of Toothbrushing Force

The purpose-designed toothbrush was capable of measuring the absolute force, in grammes, applied to the brush head, through the filament axis, while toothbrushing was performed (Allen *et al*., 1996). This was achieved by mounting two miniature foil strain guages onto an aluminium cantilever bridge housed within the hollow handle of an off-the-shelf folding toothbrush. The cantilever bridge incorporated a push-on fixture permitting attachment of a replaceable brush head, enabling simple exchange. Standard electric toothbrush heads, with nylon filaments, were used throughout. During toothbrushing, forces applied to the brush head are transmitted via the stem and elastically bend the cantilever. A miniaturized programmable micro-controller is connected to a miniature UHF radio telemetry unit for transmission to a remote personal computer. The instrument is powered by a small 6V battery. The software provided an on-line graphics display of absolute force with time (Fig. 1), indicated the mean force excluding time when no force was applied, and gave the maximum brushing force used, for each subject.

Power

Data from a previous study (Van der Weijden *et al.*, 1995) of mean toothbrushing forces (175 $\pm$ 60) in 35 subjects indicated that, to detect a clinically significant increase in mean force of 25 per cent (175–220) we would require 29 subjects for 80 per cent power.

Statistics

Comparisons within the entire cohort (all subjects) between baseline, 2 and 14 weeks were made using the paired *t*-test. Comparisons between male and female subgroups at baseline, 2 and 14 weeks were made using a two-sample *t*-test.

Results

Data were obtained for all 30 subjects (10 males, 20 females) participating in the study. The mean age of the subjects was 13·7 $\pm$ 1·1 years.

The results are summarized in Table 1. There were no significant differences between baseline recordings of toothbrushing force, and measurements made at 2 and 14 weeks in the study cohort (all subjects). No statistically significant differences in toothbrushing force were observed between males and females at any time point ($p > 0{\cdot}4$).

Discussion

Previous instruments that measured *in vivo* brushing forces employed hard wiring to transfer data from the toothbrushing instrument to the recording apparatus, which must to some extent have interfered with the subjects' brushing technique. In the present study, a cordless toothbrush instrument transmitted acquired data by radio telemetry to a remote graphics display. Some hysteresis will have occurred in the measurement of absolute loads due to the plastic material of the brush head, but this has previously been shown to be small (about 2·5 per cent; Allen *et al.*, 1996). The advent of this technology has allowed measurement of brushing forces without interfering with manipulation of the brush. We acknowledge that the instrument used to measure toothbrushing force in our study is by no means an exact replica of (although is very similar to) commercially available manual toothbrushes. It is therefore unlikely that we have quantified precisely those forces used by subjects at home, when using their own toothbrushes. Furthermore, we have not been able to control for inherent, individual, habitual toothbrushing effects and it is also likely that toothbrushing behaviour is disrupted simply by placing the patients under observation. Nevertheless, we assume that such variables, which are virtually impossible to control, are prevalent at each visit in this longitudinal study.

The study showed that placing fixed appliances did not result in alteration of the subject's habitual brushing

TABLE 1 *Mean ($\pm$ l SD) and range of toothbrushing forces (g) in 30, 10–15-year-olds measured at baseline, 2 and 14 weeks. Subjects had orthodontic appliances fitted after brushing forces were recorded at baseline*

	Mean force (g)		
	Baseline	2 weeks	14 weeks
All subjects	194 (124)	203 (77)	201 (76)
Range	(65–392)	(62–365)	(67–302)
Males	220 (136)	187 (86)	185 (88)
Females	181 (119)	212 (74)	209 (61)

95 per cent confidence interval for all subjects, baseline versus 2 weeks. Mean difference is 9 units (95 per cent CI –46 to 64).
95 per cent confidence interval for all subjects, baseline versus 14 weeks. Mean difference is 7 units (95 per cent CI –48 to 62).

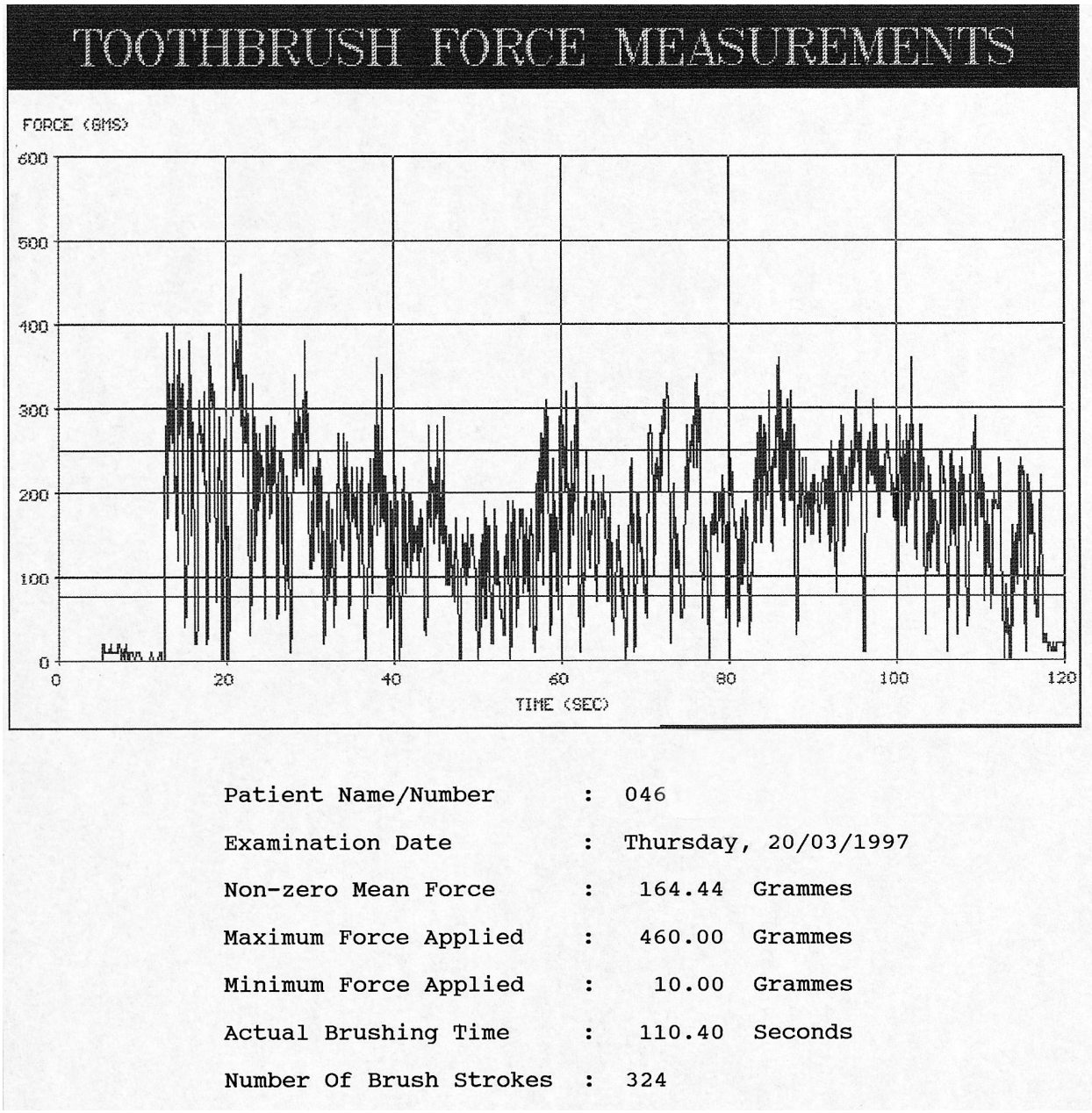

FIG. 1 Example of a force-time trace in a 14-year-old showing the force applied to the head of a toothbrush during toothbrushing, with time spent brushing. Calculation of the mean brushing force used excluded data transmitted when zero force was used.

pressures when using the experimental brush. A wide range of brushing forces was observed between individuals, although there were no observed differences between males and females. There is as yet no validated maximum atraumatic brushing force, although there seems to be a consensus from the literature for an empirical critical figure of 250–300 g.

It can be observed from the range of brushing forces in Table 1, that some subjects do use toothbrushing forces above this suggested critical figure, both at baseline and beyond. Whilst this does not imply that orthodontic patients comprise a special 'at risk' group from toothbrush abrasion of the gingiva, there is clearly some evidence that toothbrushing forces, which have been shown to cause pain and gingival bleeding (Hasegawa *et al*., 1992) are being used.

Our results are broadly consistent with those of Fraleigh *et al*., (1967) who found mean forces ranging between 124–204 g, over a wide age range depending on the type of brush head used. Heath and Wilson, (1974) recorded mean maximum forces of about 480–588 g where a scrub technique with a water saturated brush was used. In our study, the brush was not water saturated, but used with a dentifrice, so that wetting of the brush to saturation may alter the pressure used. White (1983) reported mean brushing pressures equivalent to approximately 94 g in 'poor' brushers, and 400 g in 'good' brushers. Wide variations in brushing forces were found in all of these

studies, but there were no overt disparities with our findings.

Conclusions

The finding that fixed orthodontic appliances did not reduce toothbrushing forces, as might have been anticipated, suggests that there is no particular indication to warn patients having fixed appliance therapy of a potential problem of reduction in brushing force. While sufficient pressure should be applied to remove plaque, some of larger forces recorded in this study are potentially traumatic. These data suggest that there is a need for a pressure-sensitive toothbrush to identify and monitor individuals who habitually use potentially traumatic brushing forces, and to provide oral hygiene instruction in the context of general dental practice. Further studies are required to determine the most efficacious force levels for optimum plaque removal, especially from embrasure areas, that do not result in injury to the hard and soft dental tissues.

Acknowledgements

This research was supported by Philips UK.

References

Addy M., Dummer P. M. H., Hunter M. L., Kingdom A. and Shaw W. C. (1990)
The effect of toothbrushing frequency, toothbrushing hand, sex and social class on the incidence of plaque, gingivitis and pocketing in adolescents: a longitudinal cohort study,
Community Dental Health, **7**, 237–247.

Allen, C. R., Hunsley, N. K. and Macgregor, I. D. M. (1996)
Development of a force-sensing toothbrush instrument using PIC micro-controller technology for dental hygiene,
Mechatronics, **6**, 125–140.

Bjorn H. and Lindhe J. (1966)
On the mechanics of toothbrushing,
Odontologisk revy, **17**, 9–16.

Fraleigh, C. M., McElhaney, J. C. and Heiser, R. A. (1967)
Toothbrushing force study,
Journal of Dental Research, **46**, 209–214.

Hasegawa, K., Machida, Y., Matsuzaki, K. and Ichinohe, S. (1992)
The most effective toothbrushing force,
Pediatric Dental Journal, **2**, 139–143.

Heath, J. R. and Wilson, H. J. (1974)
Forces and rates observed during in vivo toothbrushing,
Bio-medical Engineering, **9**, 61–64.

Sutcliffe, P. (1989)
Oral cleanliness and dental caries,
In: J. J. Murray (ed.) *The Prevention of Periodontal Disease*, 2nd edn, Oxford University Press, Oxford, pp. 200–217.

Van der Weijden, G. A., Timmerman, M. F., Reijerse, E., Snoek, C. M. and van der Velden, U. (1995)
Comparison of 2 electric toothbrushes in plaque-removing ability. Professional and supervised brushing,
Journal of Clinical Periodontology, 22, 648–652.

Van der Weijden, G. A., Timmerman, M. F., Reijerse, E., Snoek, C. M. and van der Velden, U. (1996)
Toothbrushing force in relation to plaque removal,
Journal of Clinical Periodontology, **23**, 724–729.

White, L. (1983)
Toothbrushing pressures of orthodontic patients,
American Journal of Orthodontics, **83**, 109–113.

White, L. and Hobbs, N. M. (1984)
A new oral hygiene strategy,
American Journal of Orthodontics, **86**, 507–515.