Observable deviation of the facial and anterior tooth midlines

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Statement of problem. It has been recommended that the anterior tooth midline be placed coincidently with the midline of the face (facial midline). The location of the facial midline depends largely on the judgment of the clinician. The amount of deviation between these 2 midlines that is noticeable to the observer has not been fully investigated.

Purpose. The observable deviation between the anterior tooth and facial midlines in a limited sample of dentate subjects was recorded.

Material and methods. Full facial-view, standardized photographs (×1/1.5) of 45 subjects, meeting very limited inclusion/exclusion criteria and undergoing routine dental treatment at Tel Aviv Dental School, were examined by 10 observers: 5 dentists and 5 nondental personnel who were given only a brief explanation of facial and tooth midlines. The examiners asked whether the facial and anterior tooth midlines deviated. The photographs then were scanned onto a computer screen, and the facial midline was determined by bisecting the distance between the medial angles of the eyes. The distance between a line perpendicular to this point and the contact point of the central incisors was measured by one calibrated examiner. The photographs were grouped according to the midline deviation: group 1, <1 mm; group 2, 1 to 2 mm; and group 3, >2 mm. Two photographs with oblique anterior tooth midlines were removed from the study because they were so easily detected. The observers' detection rates for the remaining midline deviation were compared and subjected to 1-way analysis of variance to identify significant differences at the 95% level of confidence. A post hoc Student t test was performed to identify significant differences among the groups.

Results. Dentists and nondental personnel demonstrated a similar ability to notice deviations of anterior tooth and facial midlines. Midline deviations of <1 mm (group 1) were detected by 6 of 10 observers in 4 of 29 photographs (14%). Midline deviations of 1 to 2 mm (group 2) were detected by 6 observers in 3 of 8 photographs (37%). Midline deviations of >2 mm (group 3) were detected by 6 observers in 5 of 6 photographs (83%). The greater the deviation, the higher the detection rate. Significant differences were found between group 3 and the other 2 groups ($P<.01$).

Conclusion. Within the limitations of this study, the greater the deviation of anterior tooth and facial midlines, the higher the detection rate. Nearly half of the 10 observers involved in this investigation were unable to detect midline deviations of <2 mm. (J Prosthet Dent 2003;89:282-5.)

CLINICAL IMPLICATIONS

The results of this study of a limited population suggest that, the greater the deviation of anterior tooth and facial midlines, the higher the detection rate. Nearly half of the 10 observers involved in this investigation were unable to detect midline deviations of <2 mm.

Esthetics are enhanced when the mesial surfaces of the maxillary central incisors (anterior tooth midline) coincide with the midline of the face (facial midline). Lombardi[1] noted that proper location of the dental midline is necessary for stability of the dental composition, as improper placement of the midline makes it impossible to balance the elements on either side of it. Tension is produced because of induced forces that make the viewer feel that the line must move to its proper place to produce stability and permanence.[2]

Standard complete denture textbooks recommend that the mesial surfaces of maxillary central incisors be in contact with an imaginary vertical line that bisects the face.[3-5] The midpoint of the interpupillary line, or the line from the center of the brows, typically is used to locate the facial midline. The anterior tooth midline is then determined by dropping an imaginary perpendicular line from the midpoint on the interpupillary line. It is sometimes difficult to transpose an imaginary point from the bisection of the interpupillary line to the midline of the mouth to determine the contact point of the mesial surfaces of the incisors. Other anatomic landmarks used to estimate the midline position of the central incisors in complete denture prostheses are the incisal papilla[5] and

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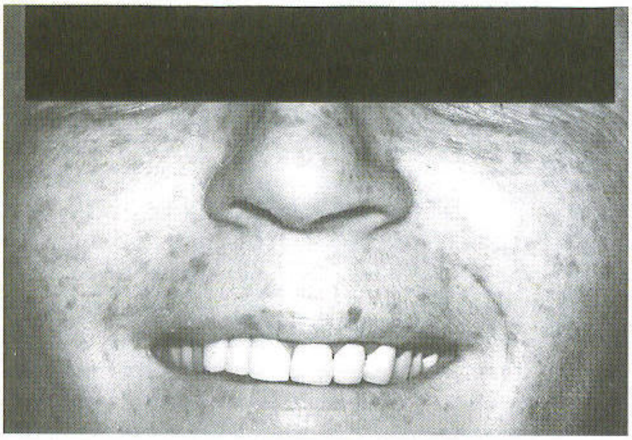

Fig. 1. Example of deviation and slanting of dental midline compared with facial midline in a patient with a provisional FPD.

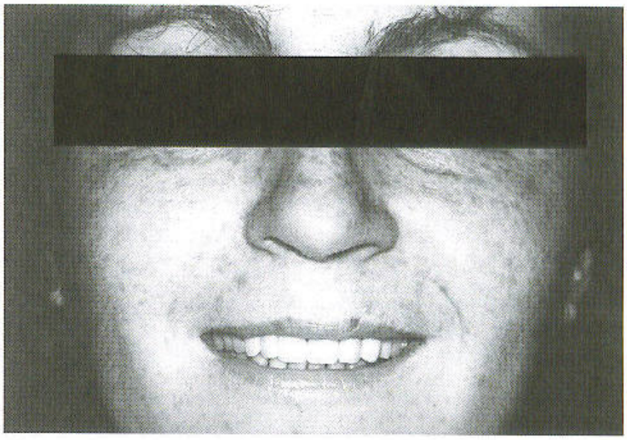

Fig. 2. Slanting dental midline made parallel to facial midline in definitive restoration of patient in Fig. 1.

a point midway between the angles of the mouth when the patient is smiling.[3]

Using the tubercle of the upper lip as the midline of the face, Latta[6] found that in 70% of 100 patients, the average distances of the midpalatal suture, nasopalatine papilla, and labial frenum were <1 mm from the midline. The clinical significance of this finding is minimal, given that the range varied by as much as 5.5 mm. Tjan et al[7] suggested that, because patients tend to relate the midline to the upper lip rather than to other facial features that are further from the mouth, an imaginary line dividing the midline lobe of the philtrum can be used to establish the midline. Miller et al[8] identified the center of the philtrum as the most reliable guide to the facial median line (facial midline). They reported that the midline of the maxillary teeth in 75% of 500 subjects examined coincided with the median line of the philtrum.

Because no human face is symmetrical, there can be no hard and fast rule for determining the facial midline; the artistic judgment of the individual clinician therefore must be used. Observation reveals that a lack of exact coincidence between the location and direction of the 2 midlines is common and not necessarily an esthetic liability. Patients with crowded, spaced, or malposed teeth who seek oral reconstruction often balk at the idea of lengthy orthodontic treatment. Figure 1 shows a patient who complained of deviation of the dental midline. Examination revealed deviation and slanting of the dental midline compared with the facial midline. The patient would not consider orthodontic treatment. Figure 2 shows the same patient after the slanting dental midline was made parallel to the facial midline without correction of the mediolateral deviation; the result was a harmonious appearance with a barely detectable tooth to facial midline deviation. Where compromise treatment is advocated, it may be possible to achieve a good esthetic result even if the anterior tooth midline is not coincident with the facial midline.

The amount of deviation of the anterior tooth midline from the facial midline that is noticeable to a viewer is unknown. The purpose of this investigation was to determine the observable deviation between the anterior tooth and facial midlines in a limited sample of dentate subjects.

MATERIAL AND METHODS

The reproduction ratio of the full facial-view to the standardized photographs was 1×1.5, where the photograph was 1 and the face size was 1.5 times the size of the photograph ($\times 1/1.5$). Photographs of 45 subjects undergoing routine dental treatment were taken. Their ages ranged from 25 to 65 years. None of the subjects had fixed or removable prostheses on their anterior teeth. All subjects were clean-shaven and had medium or high lip lines that easily exposed the complete central incisors when they smiled. There was no clinical evidence of periodontal disease. Each patient was seated in a dental chair with the headrest in a fixed position and at a constant distance from a camera mounted on a tripod. The crown length of the central incisors in the mouth and on the photographs was measured to ensure that the magnification was constant.

The photographs were examined by 10 observers, 5 general dentists and 5 nondental personnel from the administration department, all of whom worked at the Tel Aviv Dental School. The nondental personnel were given a brief explanation of facial and anterior tooth midlines. Each person was asked whether the anterior tooth midline was coincident with the facial midline and was then allowed to view each photograph from any angle and at any distance for 10 seconds. Oblique anterior tooth midlines were easily detected, even with no

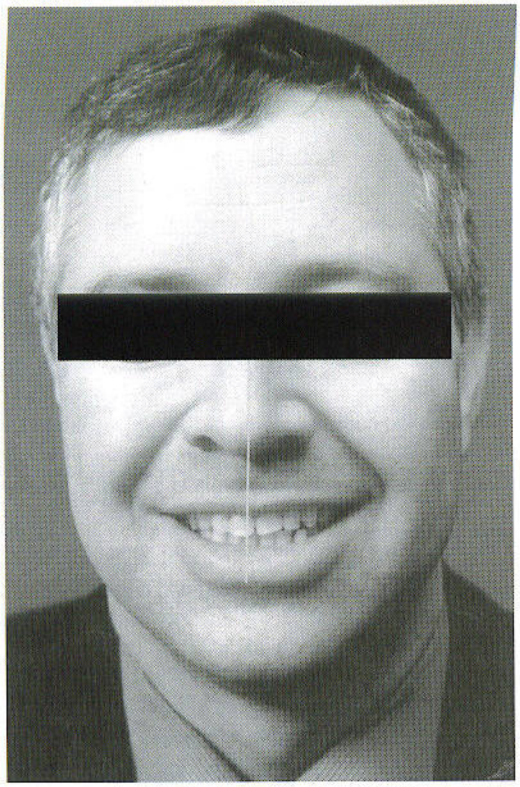

Fig. 3. Measurement of midline deviation on computer screen.

deviation of the midline. Two photographs with oblique midlines therefore were removed from this study.

The remaining photographs were scanned onto a computer screen with a specialized program (Image Editor, version 20b; Ulead Systems Inc, Torrance, Calif.) to magnify the images, which enabled better identification of the anatomic structures and facilitated measurement. The images were aligned with the interpupillary line parallel to the framework of the screen. The facial midline often is determined as the midpoint of the interpupillary line.[3-5] However, the pupils appeared dark on the computer screen, and because their margins were indistinct, their center points were difficult to identify. The nearby angle of the eye therefore was selected as a measuring point. The cursor was placed on the medial angle of one eye and moved horizontally to the medial angle of the other eye. The distance between them was recorded. This horizontal line was then bisected by a vertical line drawn perpendicular to it, down through the lips. The vertical line represented the midline of the face. The distance between it and the contact of the mesial surfaces of the central incisors was read on the computer (Fig. 3). One examiner made all measurements and determined the experimental error by measuring this distance in a similar manner on 1 photograph intermittently interposed 10 times among all others measured.

The coefficient of variation was calculated as 0.26% and was attributed to the difficulty of locating the exact points to be measured and placing the cursor on these points. The image of the midline of the teeth was not always sharp, and the medial angles of both eyes were rarely exactly symmetrical. The deviation between the anterior tooth and facial midlines of the images calculated from the computer ranged from 0 to 3 mm. The photographs were grouped according to the size of the deviation: group 1, <1 mm; group 2, 1 to 2 mm; and group 3, >2 mm. The observers' detection rates for midline deviation in the photographs were compared and subjected to 1-way analysis of variance to identify significant differences at the 95% level of confidence. A post hoc Student *t* test was performed to identify significant differences among the groups.

RESULTS

An initial comparison showed little difference in the ability of the dentists and the nondental personnel to detect deviations of the midlines in the photographs. Their results therefore were combined. In group 1 (<1 mm deviation), 6 of 10 observers detected the deviation in 4 of 29 photographs (13%) (Fig. 4). In group 2 (1-2 mm deviations), 6 observers detected the deviation in 3 of 8 photographs (37%). In group 3 (>2 mm deviation), 6 observers detected the deviation in 5 of 6 photographs (83%). The greater the deviation, the higher the detection rate.

Significant differences were found between group 3 and the other groups ($P<.01$) (Table 1). Groups 1 and 2 were not significantly different ($P>.48$).

DISCUSSION

In this investigation, deviation of the anterior tooth and facial midlines of up to 2 mm was not noticeable to almost half of the observers. It must be noted, however, that each observer's attention was deliberately directed to the midline. Without this direction, even a large midline deviation (>2 mm) might not have been noticed.

Frush and Fisher[9] suggested that the vertical long axis of the midline is more critical than its mediolateral position (Figs. 1 and 2). Provided that the central incisor midline is parallel to the facial midline, the dentist may safely place the anterior tooth midline up to 2 mm from the facial midline in this population.

In a study by Brisman,[10] the shape, symmetry, and proportion of drawings and photographs of maxillary central incisors were evaluated for esthetics. The author[9] found significant differences between evaluations made by patients and dentists, with the preferences of dental students falling in between those of the other observers. In the present study, 5 dentists and 5 nondental personnel were chosen as observers. Initially, it was expected that the ability of these 2 groups to detect deviations of

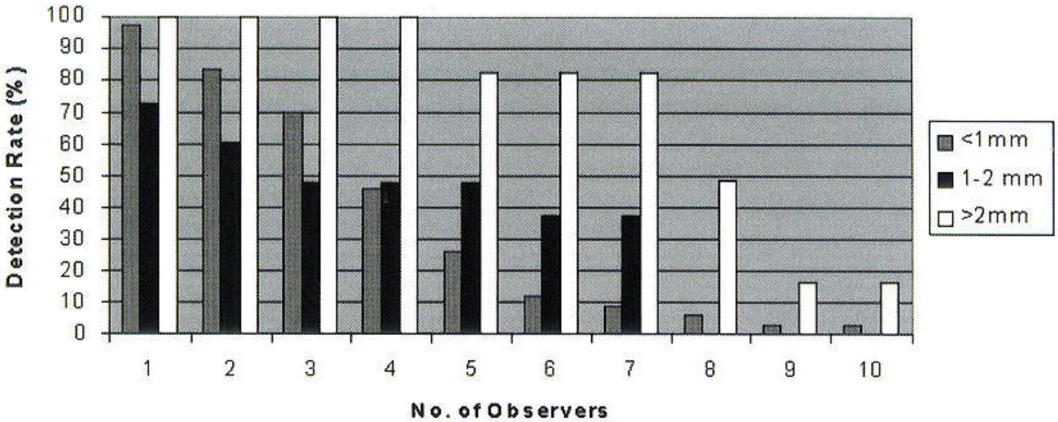

Fig. 4. Percent detection rate of anterior tooth and facial midlines deviations. To determine detection rate, number of photographs in which deviation of midline was detected by observer was divided by number of photographs in which that deviation existed. *No. of Observers,* Number who successfully detected deviation.

Table I. Summary of 1-way analysis of variance for detection rate of deviation of facial and anterior tooth midlines

Source of variation	Sum of squares	*df*	Mean square	F value	*P* value	F critical
Between groups	9388.0	2	4694.0	4.5	.02	3.3
Within groups	28276.4	27	1047.3			
Total	37664.4	29				

the anterior tooth and facial midlines might vary. There was, however, little difference with regard to their detection rates. The small size of the observer groups rendered statistical comparisons between them impractical.

Attempts were made to use the philtrum and the tubercle of the upper lip on the computerized image as the facial midline. The borders of these structures were indistinct; hence, their midpoints were difficult to identify precisely. Subjective measurements resulted in high intraobserver error and therefore were abandoned.

The results of this study cannot be compared with those of others in which anterior tooth midline deviation was measured, as no other investigation measured the observer's ability to detect differences between facial and anterior tooth midlines. The observable deviation of these midlines was determined from photographs in the present study. Detection in the patient would probably be considered more difficult, as the face is constantly moving and dynamic movements of the tissues are distracting. Patient input may be critical when features such as the position of the incisor midline are examined. The authors' experience is that patients often try to view the dental arrangement in a closer position and lift their lips and cheeks to better expose the teeth.

CONCLUSION

Within the limitations of this study, a majority of the 10 observers noticed deviations of anterior tooth midlines from facial midlines of >2 mm in magnified photographs. With deviations of <2 mm, the detection rate decreased.

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The magnitude of cutting forces at high speed

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Statement of the problem. Previous research has used a range of cutting forces for preparing teeth, but there are no data available on the forces actually imposed while cutting teeth with high-speed handpieces.
Purpose. The purpose of this study was to measure the forces imposed while cutting teeth with tungsten carbide burs used in high-speed handpieces.
Material and methods. Thirty-one dentists each cut 8 conventional class II MO and DO preparations in intact extracted third molars, by use of 2 different air turbine handpieces with different torque-speed characteristics. Two different flat fissure, plain and cross-cut tungsten carbide burs, cutting wet and dry in each handpiece/bur combination. The teeth were mounted in a custom-made transducer unit that displayed the forces imposed by the bur. Data were analysed with a 1-way ANOVA (α = .05) and Spearman correlation test.
Results. The results showed that there was no significant difference in the applied force between plain and cross-cut burs, cutting wet or cutting dry, but there was a significant difference between the high and the lower torque handpieces. The higher torque handpiece was used at a mean cutting force of 1.44 N and the lower torque handpiece at 1.20 N (P<.002). The overall general mean force observed was 1.30 N.
Conclusion. It was concluded that the forces used in cutting teeth with the tungsten carbide burs tested related both to the type of the handpiece and to the forces chosen by clinical operators. There was no difference between the plain and cross-cut burs, there was no difference between the cutting wet or dry, and the higher torque handpiece required a higher mean cutting force. (J Prosthet Dent 2003;89:286-91.)

CLINICAL IMPLICATIONS

This research illustrates that dentists should be fully aware of the power in the ultra-high speed handpieces that they use and that the applied force during cutting may become much higher than dentists anticipate. Such force may seriously damage the structure of tooth tissues and may compromise the vitality of the human dental pulp. It also introduces the need to a methodologic approach to cutting hard tooth tissues in dentistry.

Although dentists use ultra-high speed handpieces every day, the efficiency of the cutting process has never been optimized. Today's clinically used cutting tools rotate at very high speeds and are subjected to unknown forces. The force and the direction with which cutters are pressed against the tooth to achieve the desired shape of preparation are chosen and adjusted by instinct.[1]

In previous studies of tooth cutting at high speed, researchers suggested a maximum force of 3 N.[2-4] Others did not explain the rationale behind the selection of the forces used in their cutting experiments.[5-12] Some assumed that their chosen figures would be clinically acceptable,[4,13-16] whereas others obtained their figures by a subjective means.[3,18-20] Many researchers used differing forces to investigate other aspects of the cutting process[2,5,7,10,17,19-26] (Table I).

The aim of this study was to measure the forces applied by dentists when different types of high-speed handpieces and tungsten carbide burs are used to cut teeth under wet and dry conditions. It was hypothesized that different forces would be applied when cutting under each different set of conditions. The experiment was designed to simulate clinical cutting procedures as realistically as possible and then measure the forces applied while high-speed air rotors are used. The purpose of this study was to provide data that could be used when designing experiments intended to accurately reproduce the clinical cutting process for optimization.

MATERIAL AND METHODS

Two different air turbine handpieces were used: a KaVo super torque 630B (Kaltenbach & Voigt, Biber-

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Table I. Summary of some relevant previous studies

Authors	Year	Force (N)	Substrate	Purpose of study
Henry and Peyton	1951	1.96-7.36	Ivorene	Comparing the efficiency of different burs
Schuchard and Watkins	1967	0.56-8.83	Dentin	Comparing the performance of different handpieces
Westlans	1980	0.01-2.94	Teeth and amalgam	Measurement of the energy requirement of the cutting process
Semmelman, Kulp, and Kurlansik	1961	0.88	Brass	The relative function of speed and torque in the cutting process
Reisbick and Bunshah	1973	1.11	Cast iron	Wear characteristics of burs
Lloyd, Rich, and Brown	1978	0.69	Teeth	Effectiveness of cooling techniques
Brown, Christensen, and Lloyd	1978	0.29-0.69	Teeth	Measurement of energy deposition during cutting
Grajower, Zeitchick, and Rajstein	1979	1.96-3.92	Teeth & glass	Cutting efficiency of diamond wheels
Luebke, Chan, and Bramson	1980	0.69	Teeth	Cutting effectiveness of TC burs on teeth
King, Reitz, and King	1982	1.08	Composite	Comparison of burs on composite with air coolant alone and air-water coolant
Harkness and Davies	1983	0.50	Teeth	Effect of cleaning on cutting efficiency
Eames and Neal	1973	1.47	Teeth & glass	Durability of burs
Von Fraunhofer, Grieves, and Overmyer	1977	0.69 and 1.44	Teeth	Effect of lubricating coolants
Siegel and Von Fraunhofer	1996	0.50-1.47	Glass ceramic	Cutting efficiency of diamond burs
Tiara et al	1989	0.20-0.78	Glass ceramic	Comparing handpieces
Sorenson et al	1964	0.50-0.78	Dentin	Heat related to tooth structure removal
Greener and Lindenmeyer		0.88	Cast iron	Effect of geometrical shape of TC burs on cutting
Atkinson	1983	1.47	Ceramic	Significant of the blade geometry in the efficiency of TC burs

TC, Tungsten carbide

ach, Germany) with a free running speed of 325,000 rpm and a Midwest 8000I handpiece (Midwest Dental Supply, Des Plaines, Ill.) with a free running speed of 425,000 rpm. The handpieces possess distinctly different torque/speed characteristics. A maximum torque of 1.75 mNm for the KaVo handpiece and 1.15 mNm for the Midwest were measured using the methods of Walker and Morrant.[27] The KaVo handpiece was driven by a Minor driving unit (A-dec Inc, Newberg, Ore.) with air pressure regulated at 34 psi, while the Midwest handpiece was driven by a Porta Pacuttnit (A-dec Inc) with air pressure of 32 psi. Both units had a common air supply.

Plain and cross-cut tungsten carbide flat fissure burs (Jet nos. 57 and 557; Beaver Apex Dental Supplies Ltd, Tewkesbury, Gloucester, United Kingdom) were chosen because of their consistency in manufacture, which was verified by a geometrical survey of a variety of different makes (K Elias, personal correspondence, 1999). The Jet bur has consistent end-on features that do not conform to the familiar star or revelation type, although this feature was assumed not to be important in the sideways cutting in this experiment (Fig. 1).

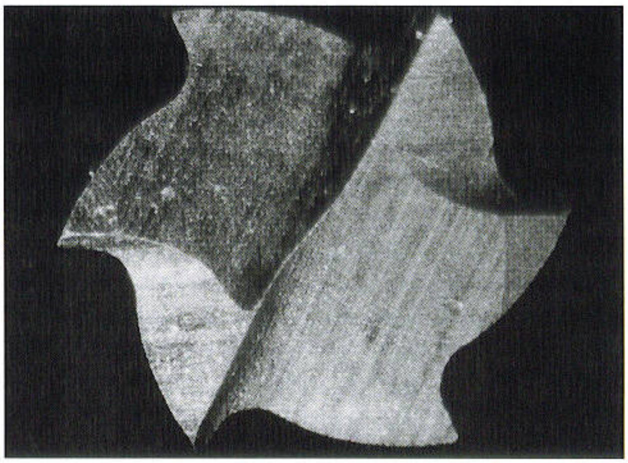

Fig. 1. End-on view of Jet bur no. 57.

A specially designed force measuring unit was constructed. It consisted of a cantilevered aluminium rod, a specimen housing unit and a casing (Imperial College, London, United Kingdom). The rod was machined in the middle to receive 2 pairs of single-element strain gauges (Type TLA 1-11; TechniMeasure, Worcester, United Kingdom) that were bonded axi-

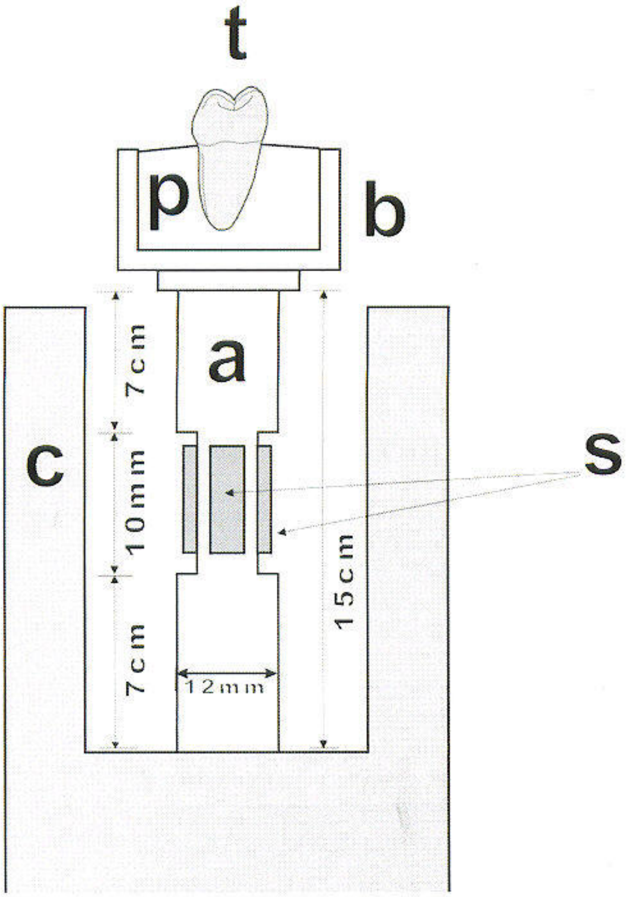

Fig. 2. Schematic diagram showing longitudinal section of force measuring unit. Diagram not to scale. *t,* Tooth specimen; *p,* plaster; *b,* brass well; *a,* aluminum beam; *s,* strain gauges; *c,* casing.

ally in 2 pairs at right angles to each other and connected in bridge circuits to give an output proportional to the sideways cutting force in any direction (Fig. 2). The strain gauges were connected to 2 conditioning amplifiers (Type 031; Solartron, Bognor Regis, Sussex, United Kingdom) with light-emitting diode digital displays, whose output was connected to a computer and to an X-Y plotter. A special software was prepared for this experiment (Medical Engineering Unit, St. Thomas's Hospital, London, United Kingdom) that allowed simultaneous acquisitions of data; recorded duration, frequency of force application, and maximum force applied; and computed the average recorded force. The assembly easily permitted placement and removal of the teeth, which were used as cut material, by use of removable metal sockets in which teeth were secured by plaster of Paris. The unit provided a firm resting point for operators' hands and allowed good vision and drainage of the cooling water spray during cutting.

Table II. Cutting times (seconds) with each bur and handpiece, shown as mean (range), N = 31

	KaVo	Midwest
57	42.4 (15-60)	39.1 (13-60)
557	40.6 (15-60)	37.6 (14-60)

The transducer was calibrated after every third operator by means of a 100-g weight (0.981 N) attached by a thread to the tooth mounting. This was taken over a pulley to provide a horizontal force. The pulley was moved around the transducer, and the amplifier outputs were adjusted to ensure equal, calibrated outputs in all directions. The transducer was accurate to ±0.01 N.

An X-Y plotter (Bryans 26000A3; Bryans Aeroquipment Ltd, Mitcham, Surrey, United Kingdom) was used to record the magnitude and direction of the force applied to the tooth. This was computed through a twin-channel amplifier (Gemini; Solartron Ltd) and displayed on a polar graph, with the radius from the origin representing the force. A limit of 3 N was chosen on the basis of other studies.[2-4]

Thirty-one dentists from the Eastman Dental Institute and Hospital and from general practice were each asked to prepare conventional class II mesio-occlusal (MO) and distal-occlusal (DO) cavities in caries-free fully-erupted third molars. Each operator prepared 8 cavities, using a new bur for each cavity, cutting wet and dry and combining plain and cross-cut burs with the KaVo and Midwest handpieces. Teeth were kept in 5% formal saline solution before being secured with plaster of Paris in a housing, which locked firmly on the transducer. Only the clinical crown was visible above the level of the plaster. The dentists were requested to use their own personal technique of cutting and were given complete freedom with regard to time, volume of water cooling spray, size of cavity, and quality of finish. Cutting force data were collected for up to 60 seconds. Cooling water and cut debris were evacuated with a mobile Virilium 5A aspirator (Virilium Co Ltd, Watford, Herts, United Kingdom). Illumination of the operating field was achieved by laboratory spotlights and was considered by all operators to be adequate.

Data were analyzed statistically by means of 1-way analysis of variance (SAS/STAT) with a significant level of .05 and by Spearman correlation test.

RESULTS

A total of 248 cavities were prepared and completed with the KaVo and Midwest handpieces. A meantime of 39.9 seconds of cutting force data were

Table III. Peak cutting forces when cutting wet or dry, shown as mean ± standard deviation (range), N = 31

	KaVo	Midwest
57 Wet	1.48 ± 0.47 (0.64-2.75)	1.19 ± 0.38 (0.25-1.94)
57 Dry	1.51 ± 0.41 (0.81-2.61)	1.25 ± 0.43 (0.20-2.18)
557 Wet	1.40 ± 0.53 (0.43-2.53)	1.12 ± 0.43 (0.22-1.82)
557 Dry	1.36 ± 0.44 (0.35-2.65)	1.22 ± 0.37 (0.25-1.91)

Table IV. Spearman correlation

Bur	Handpiece	Statistics	Significance
57 W	M v. K	0.169	0.363
557 W	M v. K	0.398	0.027
57 v. 557	M	0.648	0.000
57 v. 557	K	0.527	0.002

M, Midwest; *K*, KaVo; *W*, wet.

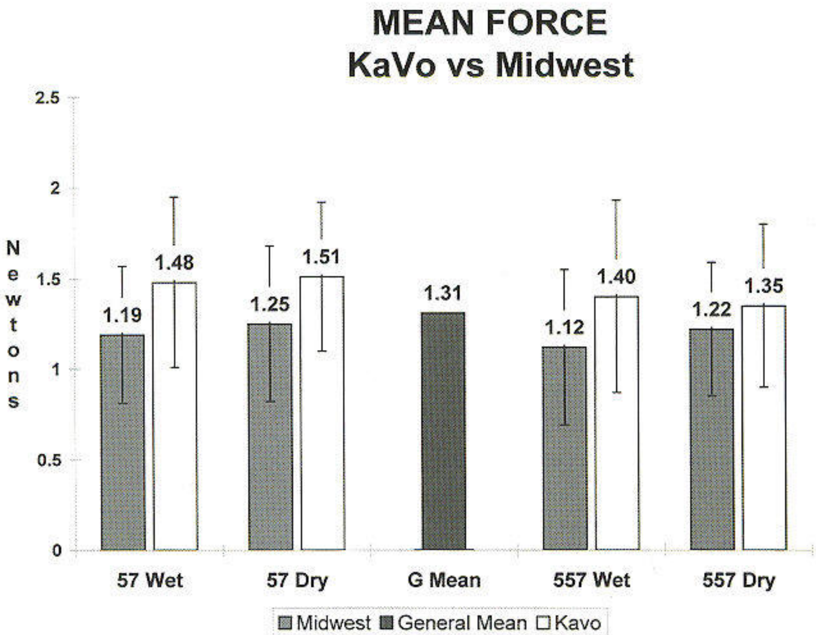

Fig. 3. Mean cutting forces applied by operators for KaVo and Midwest handpieces cutting sound wet and dry teeth.

collected for each cavity (Table II). Although the time of data collection for each cavity was limited to 60 seconds, all cavities were cut within that time, but some operators continued with fine adjustment up to 60 seconds. No bur was fractured and no dentist stalled the bur at any time, although some operators expressed their desire to run the handpieces at higher air pressure. The maximum force recorded by each dentist was assumed to be meaningful in the absence of stalling. The highest recorded force was 2.75 N and was achieved with the KaVo handpiece cutting wet with bur No. 57, whereas one operator completed the preparation of a cavity with a maximum recorded force of only 0.20 N using the Midwest handpiece and cutting dry with bur No. 57 (Table III).

No significant difference (P>.05) in cutting forces was found by analysis of variance between cutting wet rather than cutting dry or between plain and cross-cut burs (P>.05) in any applications with the KaVo handpiece group or the Midwest group, but in all situations a significantly higher cutting force was applied with the KaVo handpiece (P<.0001). Although the data showed a wide range of forces applied by the operators, most operators were consistent in their own force for all applications.

The Spearman correlation test confirmed that there was no overall correlation between the force applied to one handpiece and that applied to the other by each operator. This test also showed that if keeping to one handpiece, an operator who applied a high force with one bur did the same with another. With a particular choice of bur, there was not a significant correlation between the forces applied with different handpieces (Table IV). When the No. 57 bur cutting wet was used in the KaVo handpiece, there was no significant correlation between the peak force applied and the time spent to produce the cavity (r=0.008, P=.97).

With the KaVo handpiece, the mean maximum force recorded by each operator for all applications was 1.44 N (range 0.72 to 2.23 N). The Midwest handpiece had a significantly lower (P<.002) mean maximum force of 1.20 N (range 0.66 to 1.69 N). The overall mean force for all cavities cut was 1.31 N.

DISCUSSION

This study presented an original method to measure the force applied during simulated dental cutting. It adopted a realistic approach to conventional clinical cutting procedures, and it had an original measuring unit built solely for the study. The force measuring unit permitted the recording of the direct lateral force applied between the rotating cutting bur and the tooth substrate in all directions, and it also allowed the acquisition and recording of the horizontal directions and the patterns of the movement of the force vector during the entire cutting procedure. The pattern of cutting could allow more understanding of the clinical dental cutting process.

The exclusion of the vertical axis from force measurement in this experiment was not considered critical, because of the absence of the adjacent teeth on the cutting platform, so that all cutting could take place laterally with the bur axis almost vertical. The assembly permitted a direct sideways cutting approach, which can be achieved in clinical practice. The resilient deflection of the beam carrying the tooth and the strain gauges was evaluated by all participants as clinically representative. Therefore the sideways cutting measurements can be considered valid. It was noted that the cutting force applied by each operator varied greatly with time, including dropping to zero. This was speculated to be an intentional part of the individual operator's technique, since there was no instance of bur stalling in this study. Although there was a significant difference between the mean forces applied to the 2 handpieces (Fig. 3), and most operators used higher forces with the KaVo handpiece, some operators presented an unexplainable reverse situation.

This study showed that 22 of the 31 operators who participated in this experiment applied higher peak lateral cutting forces than the forces chosen by all previous researchers, and the lower range of all operators was higher than the figures reported in a comparable study.[26] However, the means closely confirm the values chosen by few researchers.[13,15,24]

The results confirm that the magnitude of force depended on the power of the handpiece in use rather than its free running speed and on the operator to a lesser degree. It is speculated that each operator adjusts the force applied during tooth cutting on the basis of audible feedback and so intuitively finds an operating point, which is a compromise between increasing force and decreasing cutting speed. The mean forces observed in this study of 1.44 N for the KaVo handpiece and 1.20 N for the Midwest with a general means of 1.31 N indicate that the forces used in cutting studies should relate both to the type of the handpiece and to the forces chosen by clinical operators if realistic experimental conditions are desired.

CONCLUSIONS

Within the limitations of this study, it can be concluded that the magnitude of cutting force depends on the power of the handpiece rather than the free running speed and on the operator to a lesser degree. Also, the forces chosen in cutting studies should relate to the type of handpiece if realistic experimental conditions are desired.

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