Temperature changes in dental pulp associated with use of power grinding equipment on equine teeth

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Objective To quantify the temperature changes in the dental pulp associated with equine dental procedures using power grinding equipment.

Design A matrix experimental design with replication on the same sample was followed to allow the following independent variables to be assessed: horse age (young or old), tooth type (premolar or molar), powered grinding instrument (rotating disc or die grinder), grinding time (15 or 20 seconds) and the presence or absence of water coolant.

Procedure Sound premolar and molar teeth from a 6-year-old horse and a 15-year-old horse, which had been removed postmortem, were sectioned parallel to the occlusal plane to allow placement of a miniature thermocouple at the level of the dental pulp. The maximum temperature increase, the time taken to reach this maximum and the cooling time were measured (n=10 in each study). The teeth were placed in a vice and the instrument used on the tooth as per clinical situation.

Results Significant differences were recorded for horse age (P < 0.001), instrument type (P < 0.001), grinding time (P < 0.001) and presence or absence of coolant (P < 0.001). There was no significant difference for tooth type.

Conclusion Thermal insult to the dental pulp from the use of power instruments poses a significant risk to the tooth. This risk can be reduced or eliminated by appropriate selection of treatment time and by the use of water irrigation as a coolant. The increased dentine thickness in older horses appears to mitigate against thermal injury from frictional heat.

Equine dentistry has undergone somewhat of a revival in the latter part of the twentieth century. This renewed interest has been stimulated by discovery of films made during the 1940s by Erwin Becker of Berlin University, showing detailed understanding of the anatomy, embryology and pathology of dental diseases of the horse as well as advanced treatment methods. These films demonstrate the use of powered instruments to reduce the physical effort required to perform effective dentistry in the horse. The instruments used at that time were air-driven and water-cooled. Unfortunately, they are no longer manufactured. Recently developed power instruments are either modified power drills (electrical or re-chargeable battery operated) or rotary die-grinders (air-driven or electrical ‘dremel’ types). The majority of these instruments are not water-cooled. Water-cooling when used with electrical equipment would pose a risk to operator and horse.

The lack of cooling and the associated potential thermal injuries to the teeth have concerned many operators. No published guidelines are available for routine dentistry using power instruments in the horse. Baker and Allen\textsuperscript{1} reported the use of power instruments for a sustained time (1 min and 2 min reductions) and recorded the heat produced. This heat effect was negated by the application of water cooling.

In equine dentistry, the practitioner has no indication of thermal injury from the use of power instruments. If pulp necrosis were to occur subsequent to the procedure, pulp death and perhaps tooth loss will not be evident for many years. Initially the tooth will become non-vital. This will be followed by eventual pulp infection and abscess formation. At the same time, secondary dentine production will cease and attrition may lead to pulp exposure and dental decay. In most instances, these sequelae will not be connected to a dental procedure performed some years before.

The extent of thermal change which can be tolerated by vital dental pulp tissue has been defined by both animal and human in vivo studies. In 1965, Zach and Cohen\textsuperscript{2} evaluated the thresholds for adverse pulpal responses to intra pulpal temperature rises in macaque monkeys. In the same year, the deleterious thermal effects of tooth preparation with high speed rotary instruments were studied systematically.\textsuperscript{3} In the Zach and Cohen study, a temperature rise of less than 2.2°C did not produce any histological damage to the pulp, whereas temperature increases greater than 5.5°C consistently resulted in necrosis. Accordingly, this value is regarded as the threshold value in humans for tolerating thermal insults when assessing the potential for heat-related pulpal injuries during heat generating dental procedures.\textsuperscript{4,5} For any clinical procedure, it is important to ensure that pulpal temperature increases are less than the critical value for reversible pulpal injury of 5.5°C. How closely this value resembles the thermal threshold in non-primate animals remains to be determined. Some studies suggest altered thermal threshold in animals with complex pulpo-dentinal interfaces, such as the dog.\textsuperscript{6} The detailed structure of equine dentine and dental pulp has many similarities to human dental pulp\textsuperscript{8} although, unlike their human counterparts, equine teeth maintain their length during most of the horse’s life due to the reserve crown and prolonged root formation.

Materials and methods

Teeth

The upper teeth from premolar 3 to molar 3 from both left and right maxillary arcades (10 teeth in all) were extracted from a 15-year-old mare and from a 6-year-old gelding. Both had died from non-tooth related causes; a foaling accident and euthanasia after a fracture, respectively. The teeth were identified and stored separately in open containers in a fume cupboard in an air-conditioned room. After drying, the teeth were sectioned parallel to the occlusal plane approximately 5 mm apical to the gingival margin. Previous work has shown that temperature changes in the laboratory model replicate those in vivo and do not differ significantly with an empty pulp chamber.\textsuperscript{5} Moreover, the cooling effects of air versus water in mitigating frictional heat when cutting tooth structure can be measured reliably using in vitro models.\textsuperscript{9}

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Temperature measurement
Using a retrograde endodontic approach, a K-type bead thermo-couple (diameter 0.7 mm, with measurement increments of 0.1°C) was located within the pulp chamber against the dentine directly opposite the site of grinding. The thermo-couple was coupled thermally to the dentine using heat conductive heatsink compound. The teeth were held in a steel vice, with inner tube rubber between the vice and the tooth surface to prevent conductive heat loss. After establishing the baseline temperature, recordings were made continuously during and after grinding until the samples had cooled to the baseline temperature. The following variables were recorded: (i) temperature rise (difference between baseline temperature and the maximum temperature reached); (ii) time to maximum temperature (calculated from start of grinding); and (iii) time to cool to baseline (calculated from the time point at which the maximum temperature occurred).

Instruments
All tests were completed with both a tungsten-carbide bur in an air-driven die-grinder (Air-driven Equine Dental Grinder; Lyppard, Queensland), and a tungsten chip disc (PowerFloat®; D&B Equine Enterprises Inc, Calgary). These instruments were used by the one operator, and the force applied was kept constant. The instruments were used in the manner recommended by the manufacturer.

Protocols
These protocols were performed on all 10 teeth from the 15-year-old horse and all 10 teeth from the 6-year-old horse. A time of at least 2 h was allowed between further treatments on the same tooth.

- 20 seconds die grinder (the bur was applied for exactly 20 seconds)
- 15 seconds die grinder
- 20 seconds disc
- 15 seconds disc

A further two tests were performed on the teeth from the 6-year-old horse:

- Immediate flushing with tap water (20 mL by syringe) after 20 seconds with the die-grinder
- Continuous cooling with tap water and 20 seconds with the die-grinder

Statistical analysis
Normality of data was assessed using the Kolmogorov-Smirnov test to ensure that parametric analyses were valid. Differences between groups were evaluated using repeated-measures analysis of variance (ANOVA) with post-hoc analysis of least significant differences (LSD).

Results
In terms of the maximum temperatures reached at the level of the dental pulp, significant differences were recorded for horse age (young > old; P < 0.001), instrument type (die > disc; P < 0.001), grinding time (20 seconds > 15 seconds; P < 0.001) and presence or absence of coolant (coolant < no coolant; P < 0.001). There was no significant difference for tooth type (Figure 1).

Considering the data for teeth from the younger horse as a whole, in terms of thermal stresses (Figure 1), it is clear that procedures performed without irrigation in a young horse pose the greatest risk of thermal damage. With regard to the heating and cooling patterns of the teeth, the shortest heating time (mean of 66 seconds) was seen in young horses with die grinding. Thus, there was a delay of approximately 40 seconds from the cessation of grinding to the point where the maximum temperature was reached at the level of the dental pulp.

In teeth from the older horse, both heating times and cooling times were greater (Figures 2 and 3). With most grinding methods in teeth from the older horse, approximately 10 minutes was required for these to return to their baseline temperature.

Discussion
Most horses that are stabled and fed using commercial feed develop sharp ridges (‘enamel points’) on the buccal aspects of the upper molars and the lingual aspect of the lower molars. These points cause trauma to adjacent soft tissues. Most horses require dental treatment of the posterior teeth on an annual basis to remove these points. Points are increasingly being removed using powered rotary abrasive tools with no irrigation, rather than by hand rasps.

This laboratory study examined the extent of thermal stresses to the dental pulp during powered grinding of equine posterior teeth using conditions representative of veterinary practice. The results indicate that a number of technique factors which are under the control of the operator influence the extent of thermal stress from powered grinding.

The greatest thermal insult (a mean increase of 4.62°C) occurred in teeth from the young horse when ground dry with an abrasive disc. This value is close to the threshold for thermal injury of
5.5°C. Importantly, intermittent water flushing reduced this increase to a mean of 2.14°C, and there was no measurable thermal stress when continuous water irrigation was used during grinding. This reinforces the benefit of water irrigation where this can be done safely and effectively, bearing in mind that electrical safety issues differ between battery-operated and mains powered equipment.

The results of this study indicate that horse age rather than tooth type had a considerable influence on thermal stress at the level of the dental pulp. There was a smaller increase in temperature in teeth from the older horse for any given grinding method, as well as an increased heating time and an increased cooling time. These effects can be explained by the poor heat conductivity of the thicker dentine in teeth of older animals.

A potential concern raised by the results is the extended time required for teeth to cool after 15 to 20 seconds of power grinding, which was in the order of 5 minutes for the young horse, and 10 minutes for the old horse. In the in vivo situation, it is likely that pulpal blood and the movement of saliva may facilitate cooling and thus reduce these times, however it is apparent that sufficient time should be allowed before repeated episodes of grinding on the same tooth.

In conclusion, the results of the present study indicate that powered tooth grinding poses a modest risk when undertaken in young horses using an abrasive die with no water irrigation, whereas the increased dentine thickness in older horses appears to mitigate against thermal injury from frictional heat.

References

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