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Original Article

A novel cutting machine supports dental students to study the histology of the tooth hard tissue

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Abstract *Background/purpose:* Ground section is the only way to study tooth enamel, and the conventional methods of making ground sections, grinding by hand or using a hard tissue microtome are either too time consuming or money costing. This study aimed to develop and assess a novel cutting machine in making ground sections and learning aid for dental students.

Materials and methods: By using the novel cutting machine, the students cut the embedding teeth and got 50 μm ground sections efficiently. A series of fine/coarse combination stones were used for grinding the sections to uniform 20 μm thickness. Self-made ground sections were used in the lab class of tooth tissue. Questionnaires were designed to assess the participants' attitude towards the cutting machine and their knowledge of the tooth tissue before and after making the tooth ground sections.

Results: Our findings indicated that the novel cutting machine can act as an efficient tool to make tooth ground sections. Indeed, data indicated that making tooth ground section progress can assist students' understanding of the structure and function of tooth and their pathology knowledge had improved. From a qualitative point of view, the students described making tooth ground section progress improve their practical ability and study interest in oral pathology.

Conclusion: Overall, these findings indicate that our novel cutting machine can act as an efficient tool to make tooth ground sections and support dental students to study the pathology of the tooth hard tissue in a simple and functional way.

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Introduction

The conventional methods of study hard tissues includes two ways by decalcifying or grinding into thin section.[1,2] The hard tissue of tooth includes enamel, dentine and cementum. However, in case of teeth, the mineral contents of enamel, dentin and cementum are 97%, 70% and 50% respectively, the structure of tooth hard tissue is largely destroyed in decalcified specimens.[3–5] Although tooth hard tissue structure can be studied by partial decalcification methods, the widely study way of tooth enamel, dentine and cementum is to make thin section by hand grinding or using a hard tissue microtome.[6–9] Handmade ground section is very time-consuming, date indicates that the average time of making a tooth ground section by hand is about 8—10 h. The hard tissue microtome is expensive and usually equipped for research. So it is impossible for every dental students to make a tooth ground section in oral pathology practical laboratory.

A novel cutting machine was designed by a multidisciplinary team of pathologists, dental students, engineers, which greatly improved the efficiency of making tooth ground sections. The aim of this study is to assess the quality of novel cutting machine in making ground sections and its learning aid for dental students. The overall objectives of the novel cutting machine were threefold:(i) to demonstrate the novel cutting machine can make better-quality tooth ground sections efficiently;(ii) to determine whether the process of making ground sections by using novel cutting machine was successful as an oral pathology practical laboratory reform in assisting dental students with their understanding of tooth hard tissue; (iii) to investigate students' perceptions regarding the use of novel cutting machine to making tooth ground sections.

Materials and methods

Cutting machine production

A multidisciplinary team of our pathologists, dental students, engineers developed a novel cutting machine to making tooth ground sections (Our China Patent: ZL201720287945.5). The cutting machine includes fixing device, clamp, carborundum disc, electric motor and track. The carborundum disc is driven by the electric motor. The cutting machine was pilot tested by second-year dental students (n = 30) at Sun *Y*at-sen University. From this pilot study, feedback forms were collected. Recommendations from the pilot data were used to improved the machine.

Participants

Third-year dental students, enrolled in 2015, who were undertaking oral pathology curriculum in Guanghua school of stomatology, Sun Yat-sen University, were invited to participate this study. The oral pathology curriculum taught to third-year dental students within the Department of Oral Pathology includes 40 h lectures and 44 h of practical laboratory. Enrolment in the study was voluntary. All participants were informed of the purpose and duration of the study. Overall, 116 students took part in this study. 73 of participants were female, 43 were male and the mean age of the study participants was 22 years.

Tooth ground sections making

In the experimental group, 34 teeth were embedded by epoxy resin (E51; Guanghua; China) and fixed in the track with the clamp. Then the students cut the embedding teeth and got 50 μm ground sections efficiently. A series of fine/coarse combination stones were used for grinding the sections to uniform 20 μm thickness. Finally the ground sections were placed in 70%, 80%, 95% alcohol to dehydrate, in xylene transparent 1 min and sealed.[10] Self-made ground sections were used in the practical laboratory of tooth tissue. 29 model ground sections (Oral Pathology Department, Guanghua school of stomatology, Sun Yat-sen University; Guangzhou; China) for laboratory courses were employed as the control group, which were fabricated by the conventional handpiece-cutting method previously. Ground sections of two group were scored, by two independent observers, for various features under light microscope. Intact and clear microscopic features were the criteria for a good ground section. All Data was analysed by SPSS 20.0.

Questionnaire design and data analysis

Questionnaires were designed to assess the participants' attitude towards the cutting machine and knowledge of the tooth tissue before and after making the tooth ground sections. Multiple-choice questions, rank-scale questions, likert-scale statements and binomial (yes/no) questions were utilised in the questionnaire. A test about tooth tissue knowledge was set, which composed a total of 5 questions, data collected and scores of each question were compared between participants' and controls.

All the data were exported to the Statistical Package for Social Scientists (SPSS). Frequency and percentages were used to summarise the data. Date are reported as means ± standard errors of the mean (SEM). Scores were compared between participants' and controls'. Data were

analysed using one-way analysis of variance, the post hoc Student-Newman-Keuls test. Differences with a *P* value less than 0.05 were considered statistically significant.

Results

An efficient tool to make tooth ground sections

With the new technique of the novel cutting machine, students made total 34 tooth ground sections in oral pathology practical class. 29 model ground sections (Oral Pathology Department of Sun Yat-sen University; Guangzhou; China) for laboratory courses were employed as the control group. Scores of two groups valued by two independent observers were list in Table 1. From sections made by the new technique of the novel cutting machine, we could observe the fine cemental structure such as cellular cementum, acellular cementum, and cemental lacunae (Fig. 1). Microscopic features of acellular cementum and cellular cementum with dark scattered cementocytes lacuna could be observed clearly in experimental group, while only meager acellular cementum could be found in control group. The scores of cementum features including cellular cementum and Tome's layer in experimental group were higher than those in control group ($P < 0.05$) (Fig. 2).

While observing other various features of enamel, dentin and cementum of teeth such as enamel rods, enamel-dentinal junction (EDJ), enamel spindle, we examined and compared the typical structions in the ground sections.[11] Most scores of experimental group were no less than control group. There were no statistically significant different between new-technique sections and tradition sections.

Student's opinion and perception of using novel cutting machine to make tooth ground sections

Student's opinion and perception of using novel cutting machine were investigated. Study participants were asked to rank how much did the section making class improve their interest in studying pathology of tooth with a 10-point likert scale (10 = considerably improve and 1 = no improve) after the class. The data indicated that all students considered the class being able to improve their interest, while the majority of them (82.4%) felt the class could generally improve their interest, and 17.6% regarded the class as a little boost in their interest towards pathology of tooth (Fig. 3).

Students were also asked to rank how much did the section making class improve their pratical ability with a 10-point Likert scale (10 = considerably improve and 1 = no improve) after the class. The data indicated that all students considered the class being able to improve their practical ability. 93.0% students believed the class generally improve their practical ability, and 7.0% students thought the class had a little help in improving practical ability (Fig. 3).

Students were instructed to rate the importance of the section making class to learn the structure of tooth tissue with a 10-point Likert scale (10 = considerably important

Table 1 Comparison of tooth hard tissue median scores between experimental and control groups.[a]

Group		Enamel rod	EDJ	Enamel spindle	Enamel tufts	Enamel lamellae	Dentinal tubules	Interglobular dentin	Cellular cementum	Acellular cementum	Tome's layer
Control (n = 29)	Med	5.000	5.000	4.000	1.500	4.000	4.500	4.000	3.500	4.000	3.500
	Q1	4.750	4.500	3.205	1.000	3.250	4.500	1.500	2.000	4.000	2.750
	Q3	5.000	5.000	4.500	3.500	4.500	5.000	5.000	4.250	4.500	4.000
Experimental (n = 34)	Med	5.000	5.000	4.500	3.000	4.000	4.500	4.000	4.500	4.500	4.500
	Q1	4.500	4.500	3.500	1.500	2.125	4.500	2.500	3.500	4.000	4.000
	Q3	5.000	5.000	4.500	4.500	4.500	5.000	4.500	5.000	4.500	4.500
P value		.205	.237	.258	.116	.667	.574	.884	.001*	.142	.000*

*$P < 0.01$, Mann–Whitney U Test.
[a] Based on a scale of 1–5: 1, Feature present but of poor quality; 5, Excellent view of the feature.

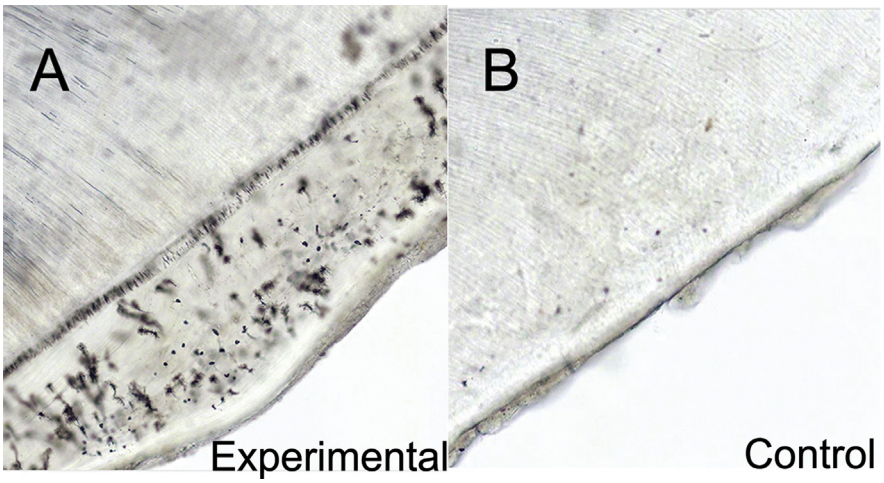

Figure 1 The fine cemental structure such as cellular cementum, acellular cementum and cemental lacunae could be seen in experimental group.

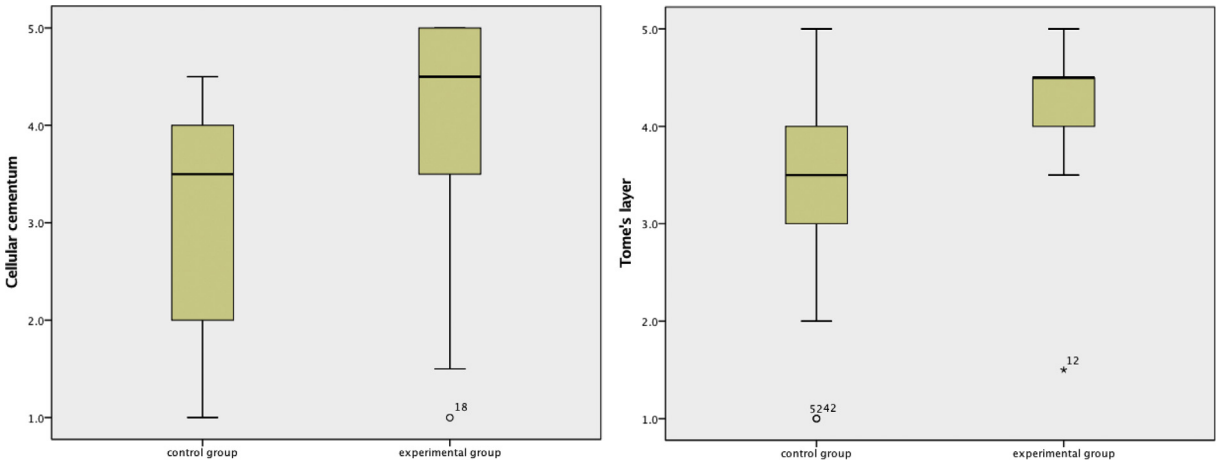

Figure 2 The scores of cementum features including cellular cementum and Tome's layer in experimental group were higher than those in control group.

and 1 = no importance). 87.7% students believed the section making class was generally important for them to learn the structure of tooth tissue while 12.3% students thought the class had a little important in learning the structure of tooth tissue (Fig. 3).

The questionnaire also contained open-ended questions to indicate whether the student cohort considered the novel cutting machine can support his study of the histology of the tooth hard tissue as a useful tool. The following were some quotations:

> "The cutting machine made it easier to make tooth ground sections, helping students to concept the structure of tooth tissue better by making the sections by themselves."

> "By doing the sections, it was easy to remember the knowledge of the tooth tissue"

> "They summarized the whole tooth ground section making process, in turn to know how to make the bone ground sections."

Learning effect of tooth tissue after using novel cutting machine to make ground sections

We examined the students' tooth tissue knowledge by a paper-based test with 5 questions after the students made the ground sections with the cutting machine, then compared with the control group, third-year dental students, enrolled in 2015, who did not make the ground sections by themselves.

In Fig. 4, the mean score of the whole test was compared between the two groups. The difference was considerable, which indicated that making tooth sections can improve students' understanding to tooth structure generally. In detail, the Fig. 5 demonstrated the percentage correct score (experimental and control group) to 5 individual questions relevant to tooth tissue knowledge. Significant improvements were determined in identifying dark zone in the experimental group (100.00% vs. 51.72%, $P < 0.001$). The experimental group also showed advantages in identifying interglobular dentin (98.25% experimental group vs.

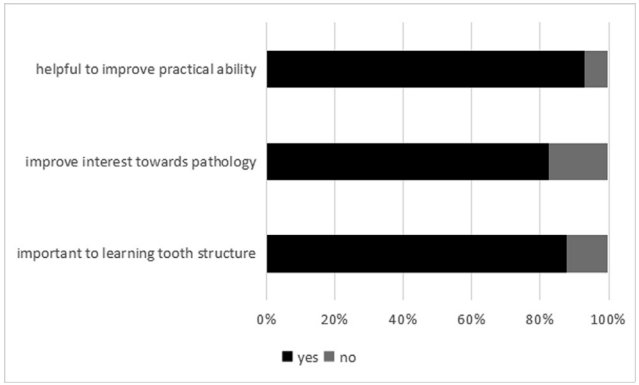

Figure 3 Student's opinion and perception of using novel cutting machine.

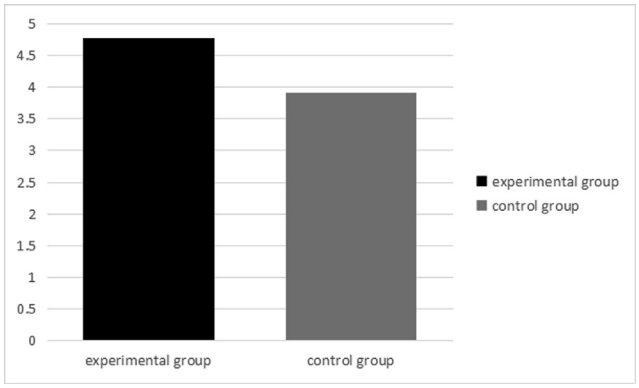

Figure 4 The mean score of the whole test was compared between the two groups.

87.93% control group, $P < 0.05$) and Malassez epithelial rest (89.47% experimental group vs. 74.14% control group, $P < 0.05$). As to identifying pulp stone and enamel-dental junction, although the percentage of the experimental score were higher than the control group, the difference was not enough ($P > 0.05$) to demonstrate the help of tooth sections making.

Discussion

Ground section is the only way to study tooth enamel, and the conventional methods of making ground section, grinding by hand or using a hard tissue microtome are either too time consuming or money costing.[2,7] So it is impossible to make tooth ground sections in routine practical laboratory due to the limitation. Data indicates our students successfully made total 34 tooth ground sections in oral pathology practical class by using the new technique of the novel cutting machine. Observation of most of the structures of tooth were not statistically different between novel cutting machine group and control group. The scores of cementum features including cellular cementum and Tome's layer in experimental group were higher than those in control group ($P < 0.05$). We speculated this is due to the fact that the epoxy resin can encapsulate the fragile cementum surrounding the teeth in the new process, and the linear cutting plane reduces the stress concentration of the dentin-cementum boundary, thus reducing the possibility of cementum fragmentation and dropping.[2,4] It is accepted that the acquisition of tooth ground sections can be facilitated by our novel cutting machine.

New added oral pathology practical laboratory, making tooth ground sections can improve student learning and interest. Knowledge of tooth tissue is central to oral histology required for clinical practice, and an understanding of tooth tissue structure is very important for many dental specialities.[8,12,13] However, learning and understanding the tooth tissue structure is challenging for the students, students perceive tissue structure as a difficult topic to visualise and memorise given the complex enamel structure names in microscopy by different calcification degree.[14,15] As a result, studies elsewhere have employed a range of

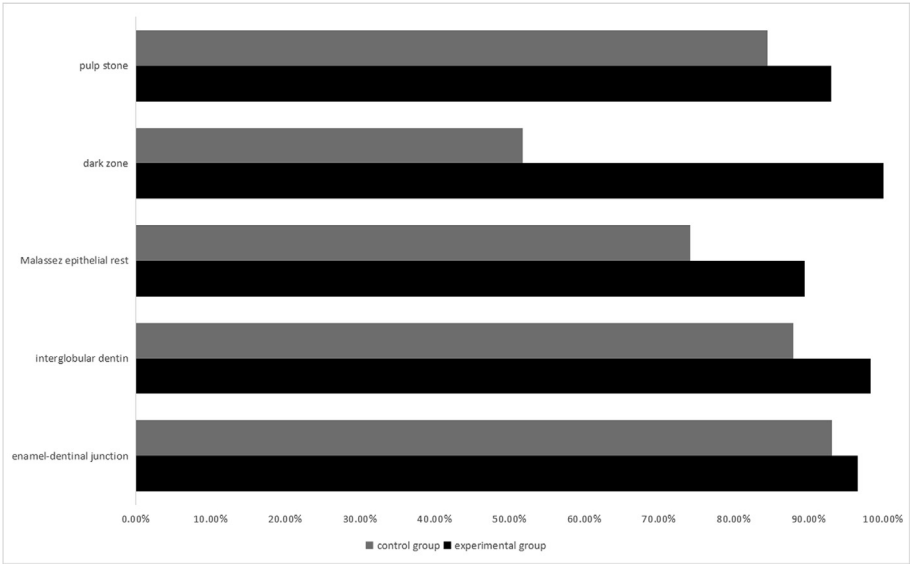

Figure 5 The percentage correct score (experimental and control group) to 5 individual questions relevant to tooth tissue knowledge was compared.

strategies to engage students in learning tooth tissue, including seeing digital slides or tooth ground section teaching video. The aim of this study was to improve students' learning effect by requiring them make tooth ground sections by themselves. The new pathology practical laboratory gets rid of the disadvantages of static observation and less manipulative opportunity in oral pathology class. By making and observing hand-made ground sections, it can deepen the students' understanding of the theoretical knowledge of dental tissue and, at the same time, increase students' interest in scientific research and hands-on ability, laying the foundation for future independent scientific research projects. In order to improve the quality and efficiency of making tooth ground sections, it is a beneficial attempt to introduce the self-made novel cutting machine into oral pathology practical laboratory. The present study highlights that all students considered the class being able to improve their practical ability and their interest to oral pathology, indicating that self-making tooth ground practical lab is a good supplement to learning tooth tissue theory.

Finally, we investigated the learning effect of tooth tissue after using novel cutting machine to make ground sections. We examined the students' tooth tissue knowledge by a paper-based test with 5 questions, then the mean score of the whole test and each question were compared. Data gathered suggested that the majority of the experimental students got higher score compared with control group. Significant improvements were determined in identifying dark zone in caries and interglobular dentin which ground sections were mostly used to observe. Although there is no statistical difference, the score of enamel-dental junction in the test was also higher than the control group. When students were making tooth ground sections, they could easily feel the different stress concentration of enamel and dentin by using the cutting machine. The ground section making experience can deepen and evoke their theoretical knowledge of enamel-dental junction. The process of making ground sections by using novel cutting machine was successful as an oral pathology practical laboratory reform in assisting dental students with their understanding of tooth hard tissue.

Conflicts of interest

All authors deny any conflicts of interest related to this study.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jds.2019.03.012.

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