Relation between Manual Dexterity and the Accuracy of Cavity Preparation

Kazuki Takahashi^{1*}, Jun Tsuruta², Ken-ichi Tonami³ and Kouji Araki¹

¹Educational System in Dentistry, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan

²Institute of Education, Tokyo Medical and Dental University, Tokyo, Japan

³Oral Diagnosis and General Dentistry, Dental Hospital, Tokyo Medical and Dental University, Tokyo, Japan

ABSTRACT

Background: Manual dexterity is important for dentists. However, few studies have investigated the relation between dental skills and manual dexterity. The hypothesis of the present study is that an association exists between manual dexterity and the accuracy of cavity preparation.

Methods: Fifty-two dental students (25 males, 27 females) participated in this study. All subjects completed manual dexterity tasks (i.e., grip strength, pinch force, and number of taps made by fingers of the right hand) and a preparation accuracy test using Virtual Reality Systems (VRS, Simodont®). For the preparation test, the cross-block body in Simodont's Manual Dexterity section was used. The associations between erroneous preparations (i.e., errors in the lateral and vertical directions) and the results of manual dexterity tasks were then analyzed and examined.

Result: The results revealed that grip strength and number of taps made by the fingers correlated with lateral direction errors. In particular, the number of taps in the first 10 s from the start of tapping made by the third finger, which the participants used as a finger rest during preparation, demonstrated a significant correlation with lateral direction errors.

Conclusion: In this work, tapping was revealed to be associated with manual dexterity by quantifying the accuracy of preparation. In addition, the agility of the third finger used as a finger rest appeared to affect accuracy in the lateral direction. VRS is useful not only in developing teaching strategy but also in research on cavity preparation.

Keywords: Manual Dexterity, Computer Simulation, Computers In Dentistry, Cavity Preparation, Virtual Reality Simulation

Introduction

Mastering clinical skills is as important as acquiring knowledge to improve the clinical competency of dental students. To help students gain clinical skills, practice using dental models in the laboratory and clinic is promoted in dental educational institutions. However, only a few scientific training methods considering personal manual dexterity have been constructed. Manual dexterity is a very complicated process. During finger movement, input, integration, and output of information in the cranial nervous system, as well as the ability to manipulate the hand to express the processed information, are required¹⁾. Hands undergo a vast range of movements, from only the fingertips to accompanying the movement of the shoulder and trunk during exercise. Hoffmann and Kilpatrick categorized hand movements into five classes, ranging from simple movement of the operator's fingertip to that involving the whole body; in this classification, movement becomes more complicated and waste and fatigue increase as the class number increases²⁾. If the relationship between such manual dexterity and dental skills is revealed, a more scientific approach for skills training can be developed.

A virtual reality system (VRS: Simodont®, MOOG, Inc., The Netherlands) was recently developed for dental skills training^{3,4)}. This system can evaluate the accuracy of cavity preparation in three dimensions and provide effective feedback to students. In the present study, the relations between items concerning manual dexterity and dental skills as measured by the VRS were investigated. The hypothesis of the present study is that an association exists between manual dexterity and the accuracy of cavity preparation.

Materials and Methods

Subjects: Fifty-two right-handed fourth-year dental students (25 males, 27 females) of the class of 2015–2016 at the Faculty of Dentistry, Tokyo Medical and Dental University, participated in this study. The participants had no clinical experience, and they provided written informed consent to participate in this study after being assured that they would not be disadvantaged by refusing to participate. The students were further assured that their test scores would not affect their prospects for future promotion. The present study was approved by the Dental Research Ethics Committee of Tokyo Medical and Dental University (approved November 6, 2015, No. 1217).

Manual Dexterity Tasks : The equipment used for this study is shown in Figures 1 and 2. The manual dexterity tasks of grip strength, pinching force, and number of taps of the first, second, and third fingers were examined. A Smedley-type grip strength meter (TAKEI, Japan, TKK 5401) was used to measure grip strength, a hydraulic pinch meter (SAMMONS PRESTON, INC., USA) was used to measure pinch force, and a Rouken-type tapping machine (TAKEI, Japan, TKK 1347) was used to measure the number of taps of the fingers.

The grip strength, pinch force, and numbers of finger taps of all of the participants were measured. Grip strength was measured so that the second joint of the first finger was orthogonal, and the grip width was adjusted such that the elbow did not separate from the trunk in an upright posture. Measurements were taken twice at an interval of 30 s for the right hand only. The average of two grip measurements was used as the final value during analysis.

Pinch force was measured between the thumb and the index and middle fingers with the fingertip knob resembling a dental turbine grip^{5, 6}.

The numbers of taps of the first, second, and third fingers over 30 s were counted at 10 s intervals. The vertical swing width was standardized to 25 mm with reference to a previous study⁷. When handling a dental air turbine, dentists adopt a posture similar to gripping a pen with three fingers, mainly the thumb and index and middle fingers, not a palm grip using all five fingers⁸. On the assumption of the pen grip manner, the three fingers were selected for measurement of the pinching force and number of taps.

Measurement of Preparation Accuracy: Measurement of preparation accuracy (Figure 2) was performed using Simodont® is a device capable of simulating and diagnosing preparations in virtual space^{3,4}.

Because none of the participants had any experience using Simodont®, pre-training was conducted for every participants. In the training, the caries preparation practice model CAR023701 was drilled using the FG 109-010 blue bar for 30s. In the pre-training, positioning during preparation was instructed. That is, each participant's elbow was positioned such that it touched his/her side, and the turbine was fixed at a position extending 90° therefrom. Similar to ordinary crown preparation, the third finger was used as the finger rest, and the turbine was held with the thumb and first and second fingers. The participants were instructed to stabilize the turbine with their thumb and second finger and hold the first finger lightly.

After pre-training, participants drilled a 4 mm-deep cross-shaped block with the FG 109-010 blue bar. Preparation

was continued until 90% of the red portion of the cross had been drilled through.

Statistical Analysis: Time elapsed (TE, time required to complete the preparation), leeway bottom (LB, erroneous preparation relative to the bottom), and leeway sides (LS, erroneous preparation relative to the sides) at completing 90% of cavity-preparation were used for following analysis.

We examined the correlations between the manual dexterity tasks, including grip strength, pinch force, and number of taps (i.e., 0–10 s, 10–20 s, 20–30 s, and total number), and the preparation data (LB, LS) using Single regression analysis. Then multiple regression analyses were performed with LB and LS as objective variables and manual dexterity tasks as explanatory variables. A stepwise method was used for the multiple regression analysis. SPSS version 20.0 for Windows (IBM, Armonk, NY, USA) was used for all statistical analyses, and the significance level was set to $p < 0.05$.

Result

Subjects of which TE deviated from the average by more than 1SD were excluded. As a result, the data of 46 subjects (22 males and 24 females) were analyzed. While no correlation between LB and each item of manual dexterity was observed, LS demonstrated a correlation with grip strength and tapping. Figure 3(A) shows the relation between LS (%) and grip strength. Using single regression analysis, a statistically significant difference between LS and grip strength was observed of the regression coefficient ($p=0.018$, $r = 0.348$).

Figure 3(B, C, D) shows the relation between LS (%) and number of taps of the first finger. During single regression analysis, a statistically significant difference between LS and tapping of the first finger from 20 s to 30 s was observed of the regression coefficient ($p=0.0472$, $r = 0.294$). Figure 3(E, F, G) shows the relation between LS (%) and number of taps of the second finger. No statistically significant difference between these items was observed. Figure 3(H, I, J) shows the relation between LS (%) and number of taps of the third finger. During single regression analysis, statistically significant differences between LS and tapping of the third finger from 0 s to 10 s ($p=0.006$, $r = 0.397$) and from 10 s to 20 s ($p=0.0119$, $r = 0.368$) were observed of the regression coefficient.

In multiple regression analysis, a statistically significant correlation was observed only between LS and tapping of the third finger from 0 s to 10 s ($p=0.006$, $\beta = -0.397$, $B = -0.224$, $r = 0.397$, $r^2 = 0.1577$, $n = 46$). (Table 1).

Table 1: The results of multiple regression analysis for LS and manual dexterity tasks.

Variables	B	SE	β	t	p	95%CI
Intersept	19.654	3.424				
Tapping the third finger(0-10s)	-0.224	0.078	-0.397	-2.866	0.006	-0.382-0.067
R=0.397, Model R2=0.157, N=46						

Explanatory variables: Grip Strength, Tapping the first finger(0-10s), Tapping the first finger(10-20s), Tapping the first finger(20-30s), Tapping the second finger(0-10s), Tapping the second finger(10-20s), Tapping the second finger(20-30s), Tapping the third finger(0-10s), Tapping the third finger(10-20s), Tapping the third finger(20-30s)

Fig. 1: Three manual dexterity tasks, A: Sumedley type grip meter; B: Hydraulic pinch meter; C: Rouken type tapping machine.

Fig. 2: Measurement of preparation accuracy, A: Simodont©; B: Participants drilled a 4 mm-deep cross-shaped block with the FG 109-010 blue bar..

Fig. 3: Correlations between LS and manual dexterity.

Discussion:

Leeway Sides and Manual Dexterity: Among the manual dexterity tasks adopted in this study, grip strength and pinch force are related to the function of flexor muscles; tapping uses both the flexor and extensor muscle groups⁵⁻⁷. Correlations between LB and many tapping items were demonstrated in this study, which suggests that both the force of the flexor muscles and the flexibility of the extensor muscles are necessary for turbine control during lateral preparation.

The participants generally moved their fingertips during tapping with maximum effort. The energy consumed in the early stages of tapping is anoxic in nature but becomes aerobic as accumulation of lactic acid in the muscle decreases the tapping rate⁹. Although several items of tapping indicated correlations with LS in univariate analysis, the only statistically significant difference found during multiple linear regression analysis was tapping of the third finger from 0 s to 10 s ($p=0.006$, $r = 0.397$). This result suggests that anaerobic exercise of the finger used as the finger rest (i.e., the third finger) is related to lateral preparation accuracy. Thus, devising training to strengthen the instantaneous force of the third finger used in the finger rest would help improve lateral preparation accuracy.

Although grip strength exerted a significant influence on LS during single regression analysis, no statistically significant difference was found during multiple regressions analysis. In previous studies on grip strength, the number of taps of the third finger correlated with the muscle mass of the body, and muscle mass has been reported to be significantly related to manual dexterity^{10, 11}. Although grip strength is also an indicator of manual dexterity, tapping of the third finger might possibly be a stronger factor affecting the lateral preparation of the beginner's dentists.

Leeway Bottom and Manual Dexterity: Despite the existence of multiple factors showing correlations with LS, no factors showed any correlation with LB. The preparation in the vertical direction may be influenced by factors other than muscle mass and agility of the muscle group of the fingers. Among other candidates of the factors influencing accuracy in the vertical direction, experience and spatial cognitive function are the most notable; further research in this field is necessary.

Simodont® as Evaluation Equipment: Simodont®, a simulator for dental students, was developed in the Netherlands⁷. The technology allows training preparation and diagnosis in virtual space without requiring artificial teeth and has been used for student training even in countries other than the Netherlands¹². The simulator integrates tactile sense in practice in a manner different from that by other

VRS techniques^{13, 14}. Earlier research has indicated that Simodont® is useful for practicing dental treatments and can be used as equipment for training and acquiring research data¹⁵. Studies on using Simodont® for dental education have been published, but no research on the relationship between Simodont® and manual dexterity has yet been reported¹⁶⁻¹⁸. This study is the first to discuss this subject.

Manual Dexterity Tasks: Several tests to examine the function of the hand, such as the nine-hole peg test and the Purdue pegboard, have been developed^{19, 20}. However, few studies have examined the association between manual dexterity and dental clinical skills. Currently, all manual dexterity tests, including those mentioned above, include many elements of cognitive functions. This study aimed to quantify only the muscular strength of the fingers; therefore, the tests were restricted so that only muscular strength could be measured.

Conclusion

The results of the present study indicate that the hypothesis, i.e., an association exists between manual dexterity and the accuracy of cavity preparation, is acceptable. Grip strength and tapping appeared to be quantitative indicators of lateral preparation skills. In particular, the number of taps made at the beginning of the exercise by the finger used as the finger rest (i.e., the third finger) significantly affected the lateral accuracy of the dental preparations. Grip strength, pinch force, and number of taps did not affect the accuracy of the preparations in the vertical direction.

Simodont® can be used not only as a VRS for dental treatment training but also for quantitative research on preparation accuracy.

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***Corresponding author:**

Kazuki Takahashi, 1-5-45 Yushima, Tokyo, 113-8549, Japan,

Phone: +91 81-03-5803-4577

Email: k.takahashi.dal@gmail.com

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