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Online colour training system for dental students: a comprehensive assessment of different training protocols

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SUMMARY The purpose of this study was to evaluate the training effect and to determine the optimal training protocol for a recently developed online colour training system. Seventy students participated in the evaluation. They first completed a baseline test with shade guides (SGT) and the training system (TST), and then trained with one of the three system training methods (Basic colour training for group E1, Vitapan Classical for E2, and Vitapan 3D-Master for E3) or shade guides (group C1) for 4 days. The control group (C2) received no training. The same test was performed after training and they finally completed a questionnaire. The correct matches after training increased in three experimental groups and group C1. Among experimental groups, the greatest improvement of correct matching number was achieved by group E3 (4·00 ± 1·88 in SGT, 4·29 ± 2·73 in TST), followed by E2 (2·29 ± 2·73 in SGT, 3·50 ± 3·03 in TST) and E1 (2·00 ± 2·60 in SGT, 1·93 ± 2·96 in TST). The difference between E3 and E1 was statistically significant (*P* = 0·036 in SGT, 0·026 in TST). The total average training time was shorter in group E2 (15·39 ± 4·22 min) and E3 (17·63 ± 5·22 min), with no significant difference between them. Subjective evaluations revealed that self-confidence in colour matching were improved greater in group C1 and E3. In conclusion, all tested sections of the system effectively improved students' colour-matching ability. Among system training methods, Vitapan 3D-Master showed the best performance; it enabled greater shade-matching improvement, it saved time and was superior in subjective evaluations.

KEYWORDS: colour training, dental aesthetics, online system, dental education, training programmes, tooth colour

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Introduction

Shade selection by matching natural teeth with shade guide tabs is common practice in dentistry today. However, the process is affected by a number of factors, such as lighting conditions (1–3), coverage errors and colour distributions of shade guides (4). Furthermore, visual shade selection is a subjective process and an individual's experience, fatigue, ageing and colour perceptual ability will contribute to inconsistency (2, 5–7). Indeed, visual shade selection has been demonstrated to be inaccurate and lack consistency within and between individuals (8–11). According to Okubo *et al.* (8), in a 'Vita-Vita' test of Vita Lumin shade tabs by 31 examiners, only a 48% correct match resulted. A later study reported 56% accuracy (12). Moreover, visual shade selection was less accurate and less reproducible than a spectrophotometric shade assessment in numerous studies (9, 13).

Colour teaching, training and experience can improve the colour-matching ability of dental professionals. Hammad (11) reported that prosthodontists demonstrated significantly superior intra-rater repeatability comparing with general practitioners. Dagg *et al.* (2). demonstrated that experienced observers

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had better shade selection results than novices (2). Both colour science education and colour training can improve the quality of shade matching (14). Bergen (15) developed the first training programme to improve dentists' colour-matching skills. Scores were improved in the study groups upon retesting. Colour training software was introduced by Paravina (16). With the 'Vita-Vita' test, subjects scored 69·4% correct matches at baseline, and 82·5% after training for 40 min with the 'Colour Training Exercises' software. In 2002, Jakstat developed a shade selection training system specially for university students, which was known as 'Toothguide Trainer (TT)' and 'Toothguide Training Box (TTB)' (17). It was based on the 3D-Master Toothguide. This programme has been integrated into the pre-clinical training curricula at the University of Leipzig since 2004, as well as many other universities (18). Several studies (17–20) showed that it led to improvement in the ability of colour differentiation.

In a previous study, the author developed and evaluated an online colour training system (21); 37 students were trained with the Basic colour and Vitapan Classical matching exercises. The 'Vita-Vita' test showed that the average correct match increased from 41·88% at baseline to 71·13% after training. The evaluation was preliminary; participants practised only with Basic colour and Vitapan Classical exercises. The 3D-Master training exercise, the corresponding shade guides for which are used extensively in dental clinics and most frequently taught in colour teaching (22), was not evaluated. Additionally, the effects of training with real shade guides and the comparison with online training were unclear.

The purpose of this study was to evaluate the effectiveness of different colour training protocols of the online colour training system and to identify the optimal protocol. The hypothesis tested was that the colour training protocols would have similar effects in terms of improving the colour-matching abilities of dental students.

Materials and methods

Configuration of the colour training system

The online colour training system (http://www.t-smile.cn:8080/ColorTrainingSystem/system.jsp) was introduced in a previous study (21). It contained three parts: Basic colour training, Shade guide matching (Vitapan Classical, Chromascop, Shofu NCC, and Vitapan 3D-Master) and clinical shade selection simulation. Basic colour training and Shade guide matching, including Vitapan Classical and 3D-Master, were evaluated in this study.

In Basic colour training, the samples were presented as rectangles with different colours. It included value and chroma training; each contained matching and ranking exercises. Vitapan Classical training generally mimicked the corresponding namesake shade guide. The shade tabs of groups A, B, C and D were trained separately in level 1, groups A with B and groups C with D were then trained together in level 2, and all four groups were finally mixed in level 3. In the 3D-Master section, students were trained in three steps (first lightness, second chroma, third hue; Fig. 1), simulating the shade selection sequence with the 3D-Master shade guide.

The online colour training system was developed using the Java language on an Eclipse platform. Images of the shade tabs were captured using a Crystaleye spectrophotometer* with a Shofu gingival matrix as the background. Users logged into the system with their own usernames and passwords. Training data, such as correct matching numbers and training times, were automatically recorded in the database.

Evaluation and training protocol

In total, 70 colour-normal dental students (21 males, 49 females; average age 22·35 years) from Peking University School of Stomatology participated in the evaluation and training programme. The participants were in their second to fifth years and had not been trained in visual tooth shade determination before. This study has been approved by the Ethics Committee of Peking University School and Hospital of Stomatology. Each participant enrolled in this study has signed the informed consent. They were equally balanced in terms of gender and age and were then divided into three experimental groups and two control groups (n = 14 for each group). A 30-min lecture entitled 'Introduction to the online colour training system' was provided for the participants. They first

*Olympus, Tokyo, Japan.

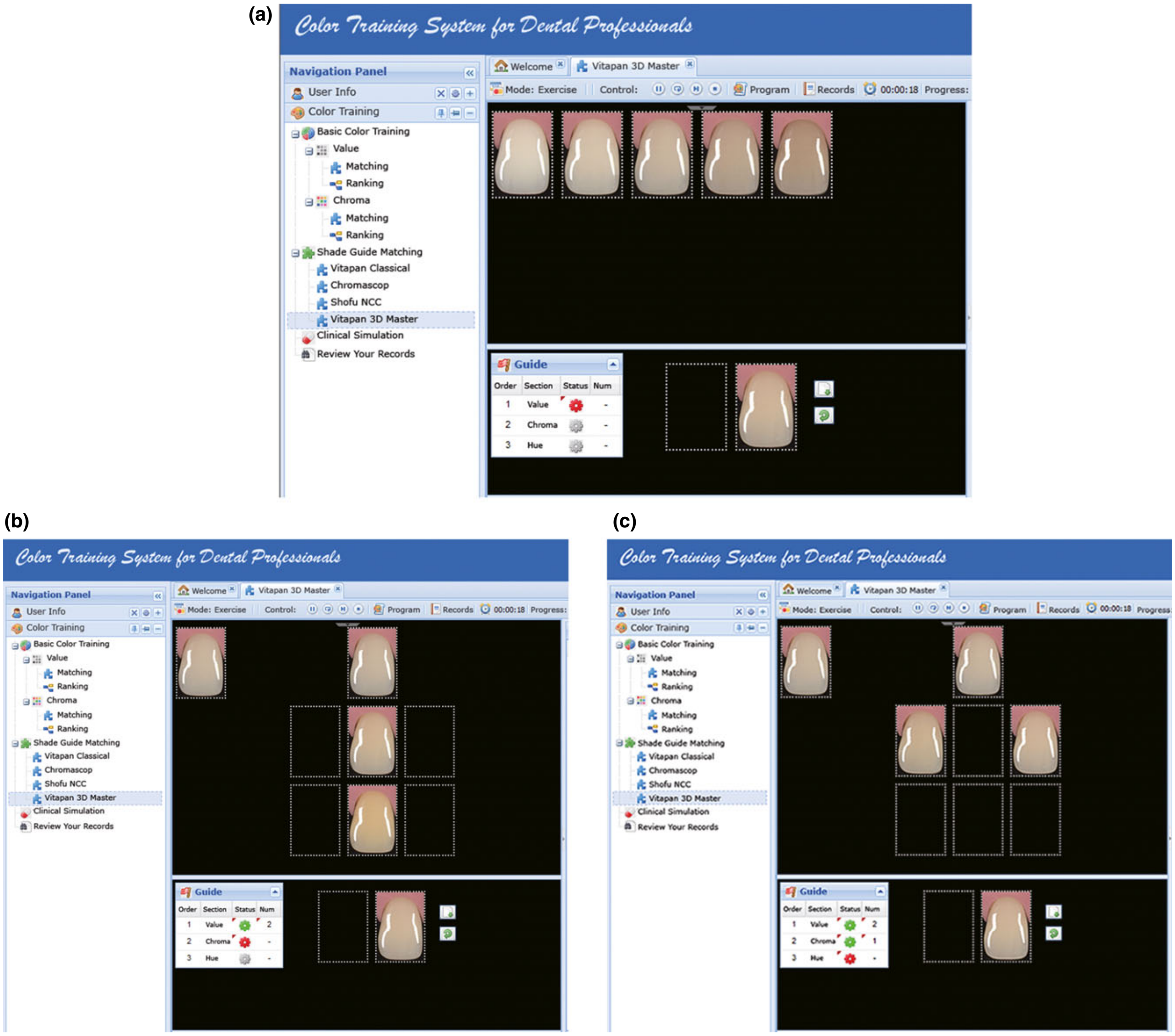

Fig. 1. Vitapan 3-D Master shade guide matching: A. Value selection; B. Chroma selection; and C. Hue selection.

went through the 'Vita-Vita' test (Vitapan Classical shade guides) on a black background under natural light between 10:00 AM and 2:00 PM. The matching results and time spent were recorded. Then, 1 month after the examination, all the students were tested with the colour training system using the Vitapan Classical level 3 in black background. During the next 4 days, experimental groups trained with the system using their own computers (all used LCD monitors), control group 1 trained with the Vitapan Classical shade guides ('Vita-Vita' exercises), and control group 2 received no training. All groups except C2 practised twice with their own exercise per day. Students in experimental groups and group C2 were not permitted to use shade guides after the baseline test. When the training programme was finished, students were retested first with the system and then with shade guides within 1 week. At the end of the final test, participants, except group C2, were required to complete a questionnaire related to the use of the colour training system and training protocol (Fig. 2).

The baseline and after-training test results were compared using a paired-sample t-test, as were the results of shade guide and system tests. Differences between each group were compared by one-way ANOVA. All levels of significance were set at $P < 0{\cdot}05$.

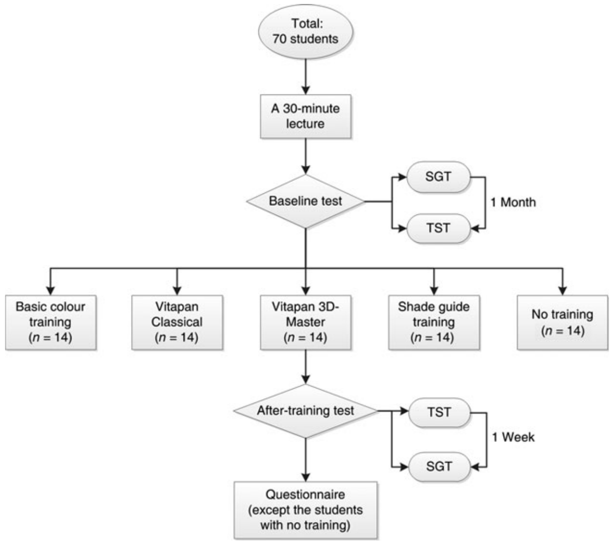

Fig. 2. Flow chart for interpretation of the training process and grouping method.

Data analyses were performed using the SPSS software (ver. 13.0 for Windows†).

Results

Intra-group comparisons

The average correct matches for both tests increased significantly after training in all groups, except group C2 (Table 1). The maximum scores for both shade guide test (SGT) and training system test (TST) were 16·00. Participants in group C1 ($P < 0{\cdot}001$ in SGT), group E2 ($P = 0{\cdot}005$ in TST) and group E3 ($P = 0{\cdot}002$ in TST) spent much less time on the test after training, while the other groups took almost identical time on before- and after-training test of both SGT and TST.

Intergroup comparisons

Correct matching improvements in all experimental groups and group C1 were significantly higher than those of group C2 in both tests (except E1 vs. C2 in TST, $P = 0{\cdot}173$, Table 2). In SGT, the enhancement of correct matches in group C1 was significantly higher than that of experimental groups, while the corresponding differences in TST were not significant. In both SGT and TST, the correct matching enhancement of group E3 was significantly higher than that of E1 ($P = 0{\cdot}036$ in SGT, 0·026 in TST) and slightly higher than that of E2, and the improvement of group E2 was slightly higher than that of E1.

†SPSS Inc., Chicago, IL, USA.

Comparison of the results by the two test methods

In the before- and after-training tests, both correct matches and test times for SGT were slightly higher than the corresponding values for TST, except for the test times in before-training tests (Table 3). However, the differences between SGT and TST were not statistically significant in both correct matching and test time comparisons. Analyses of the total average values for before- and after-training tests got the same results.

Training time comparisons among system training items

The average time spent by group E1 in Basic colour training was 25·59 min; this was the longest (Table 4). Group E2 required 15·39 min to finish the Vitapan Classical exercises and group E3 needed 17·63 min to complete the Vitapan 3D-Master exercises; the difference between group E2 and E3 was not significant ($P = 0{\cdot}191$).

Training and test results in group C1

The mean correct matches and training times for the shade guide exercise are shown in Fig. 3. The number of correct matches increased and the time required decreased as participants practiced more. The number of correct matches increased rapidly in the first 2 days. At the end of the training programme, all 14 students achieved 16 correct matches; this level was maintained until the final SGT.

Subjective evaluations

Of the 56 participants, 35 (62·50%) stated that there were differences between the digital and real shade guides, while the other students reported that the two were almost identical. All participants (56) confirmed that the training was helpful; 39 (69·64%) thought it was of some help and 17 (30·36%) thought it was of great help. The changes in self-confidence in the 'Vita-Vita' tests before and after training are shown in

Table 1. Comparisons of correct matching number (*n*) and testing time (min) between before- and after-training test for each group (*n* = 14). The data are recorded as mean (SD)

	Before training		After training		After-before			
	n	min	*n*	min	*n*	*P*-value	min	*P*-value
SGT								
E1	9·26 (2·55)	14·94 (7·83)	11·29 (3·71)	15·84 (5·95)	2·00 (2·60)	**0·013**	0·90 (4·75)	0·490
E2	9·29 (2·33)	13·43 (5·85)	11·57 (2·71)	14·86 (4·21)	2·29 (2·73)	**0·008**	1·44 (5·58)	0·353
E3	9·00 (2·75)	13·92 (5·60)	13·00 (2·04)	13·97 (3·42)	4·00 (1·88)	**<0·001**	0·05 (6·21)	0·976
C1	9·71 (3·12)	12·49 (3·04)	16·00 (0·00)	7·43 (1·53)	6·29 (3·12)	**<0·001**	−5·06 (2·76)	**<0·001**
C2	9·57 (3·13)	12·82 (5·46)	9·64 (1·91)	14·20 (8·59)	0·07 (1·77)	0·883	−1·69 (5·71)	0·289
TST								
E1	9·28 (3·77)	14·69 (9·71)	11·21 (3·64)	12·02 (7·01)	1·93 (2·96)	**0·016**	−2·66 (6·64)	0·157
E2	8·14 (3·06)	12·51 (5·97)	11·64 (2·02)	6·03 (3·46)	3·50 (3·03)	**0·001**	−6·48 (7·20)	**0·005**
E3	9·43 (2·74)	14·34 (4·35)	13·71 (2·05)	8·88 (3·99)	4·29 (2·73)	**<0·001**	−5·46 (5·26)	**0·002**
C1	9·86 (4·05)	14·12 (6·36)	12·86 (2·25)	15·23 (8·51)	3·00 (3·35)	**0·005**	1·11 (8·45)	0·632
C2	9·29 (3·56)	13·52 (5·72)	9·79 (4·17)	15·35 (8·71)	0·50 (1·70)	0·291	1·83 (8·61)	0·441

The bold values represent the *P*-value < 0.05.

Table 2. Comparisons of correct matching enhancement† between different groups according to SGT and TST (*n* = 14 for each group)

Group A† vs. B†	Mean difference (A-B)	*P*-value	95% CI Lower	95% CI Upper
SGT				
E1 vs. C2	1·93	**0·043**	0·05	3·80
E2 vs. C2	2·21	**0·021**	0·34	4·08
E3 vs. C2	3·93	**<0·001**	2·06	5·79
C1 vs. C2	6·21	**<0·001**	4·34	8·08
E1 vs. C1	−4·29	**<0·001**	−6·16	−2·42
E2 vs. C1	−4·00	**<0·001**	−5·87	−2·13
E3 vs. C1	−2·29	**0·017**	−4·16	−0·41
E1 vs. E2	−0·29	0·761	−2·16	1·58
E1 vs. E3	−2·00	**0·036**	−3·87	−0·13
E2 vs. E3	−1·71	0·072	−3·58	0·15
TST				
E1 vs. C2	1·43	0·173	−0·64	3·50
E2 vs. C2	3·00	**0·005**	0·93	5·07
E3 vs. C2	3·79	**0·001**	1·72	5·86
C1 vs. C2	2·50	**0·019**	0·43	4·57
E1 vs. C1	−1·07	0·305	−3·14	0·10
E2 vs. C1	0·50	0·631	−1·57	2·57
E3 vs. C1	1·29	0·219	−0·78	3·36
E1 vs. E2	−1·57	0·134	−3·64	0·50
E1 vs. E3	−2·36	**0·026**	−4·43	−0·29
E2 vs. E3	−0·79	0·451	−2·86	1·28

†Correct number difference between before- and after- training tests (after-before). The bold values represent the *P*-value < 0.05.

Table 5. Grades 1, 2 and 3 corresponded to uncertain (UC), confident (C) and very confident (VC). The degrees of grade enhancement in descending order were group C1, E3, E2 and E1, the rankings of which were the same with the correct matching improvement in SGT and similar with those in TST (E3 > E2 > C1 > E1).

Discussion

In this study, the effectiveness of colour training using online systems and shade guides was confirmed. The 4-day training programme increased the correct matches for all participants and decreased the test times in some groups in the final tests. Comparison of the improvements among these groups leads inevitably to rejection of the study hypothesis. The various training protocols produced quite different effects on the improvement in the colour-matching ability of the participants.

Colour selection is a subjective issue and affected by various factors (e.g. experience, gender and environments) (2) and can be improved by a variety of training exercises, such as colour samples, software and online training system. When using colour samples in a dental class, many samples are needed to ensure that all students receive adequate training, and recording of training data is labour intensive. Software is more efficient because it records the training data for each user; however, collecting the data of the whole class is inconvenient. The online colour training system is the most efficient because all training data are recorded automatically. Compared with those previous colour training systems like Toothguide Trai-

Table 3. A comparison between SGT and TST in correct matches and test times (min) (n = 70). The data are recorded as mean (SD)

	SGT	TST	Mean difference (SGT-TST)	P-value
Correct match				
Before training	9·37 (2·72)	9·20 (3·42)	0·17 (3·97)	0·719
After training	12·30 (3·17)	11·84 (3·19)	0·46 (3·70)	0·305
Total	10·84 (3·29)	10·52 (3·55)	0·31 (3·82)	0·332
Test time				
Before training	13·67 (6·15)	13·83 (6·36)	−0·16 (9·03)	0·882
After training	12·80 (5·06)	11·50 (7·47)	1·30 (9·71)	0·266
Total	13·24 (5·63)	12·67 (7·01)	0·57 (9·37)	0·473

Table 4. Mean (SD) training times (min) of different system training items (n = 14 for each group)

Basic colour training	Time	Vitapan Classical	Time	Vitapan 3D-Master	Time
Value matching Level 1	1·92 (0·97)	Vita Classical Level 1	1·98 (0·86)	Vitapan 3D-Master	17·63 (5·22)
Value matching Level 2	2·18 (1·22)	Vita Classical Level 2	4·18 (1·46)		
Chroma matching Level 1	2·98 (1·56)	Vita Classical Level 3	9·23 (3·47)		
Chroma matching Level 2	1·60 (0·72)				
Value ranking Level 1	3·83 (2·06)				
Value ranking Level 2	4·52 (2·56)				
Chroma ranking Level 1	4·58 (2·01)				
Chroma ranking Level 2	3·97 (1·78)				
Total	25·59 (8·88)		15·39 (4·22)		17·63 (5·22)

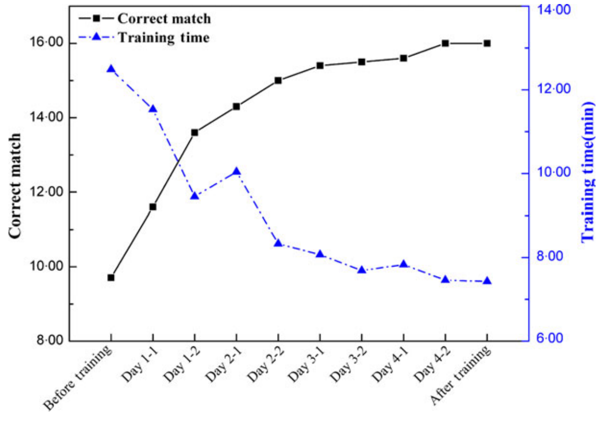

Fig. 3. Mean correct matches and training times (min) of shade guides exercise at the baseline test, daily training (twice per day), and at the test after training.

ner which was based especially on the 3-step shade-matching method (18), the online colour training system evaluated in the present study included not only four kinds of Shade guide matching training methods, but also Basic colour and clinical simulation training approaches, thus providing participants with various training options. The digital shade guides to be evaluated included Vitapan Classical and 3D-Master patterns, which were regarded as the most popular shade guides (23). Previous studies did not compare the effects of digital materials with real shade guides, or the Vitapan Classical with the 3D-Master pattern. The most effective and efficient colour training protocol has been unclear.

The design methodology used here was randomized controlled with three experimental groups, one positive and one negative control group. After the 4-day training programme, all groups that performed exercises showed significant improvements in both tests, while those with no training exhibited no changes. Participants who undertook real shade guide matching exercises scored 100% correct matches and made

Table 5. Subjective evaluation – number of students who reported self-confidence improvement on the before- and after-training tests and grade enhancement for each group except C2 (n = 14)

	2 grades enhanced	1 grade enhanced		0 grade enhanced		Means (SD) for
	UC-VC†	C-VC	UC-C	C-C	UC-UC	grade enhancement
E1	0	0	8	5	1	0·57 (0·51)
E2	1	0	9	3	1	0·79 (0·58)
E3	2	4	5	3	0	0·93 (0·62)
C1	6	4	3	1	0	1·36 (0·63)

VC, very confident; C, confident; UC, uncertain.
†The self-confidence changes from uncertain in the before-training test to very confident in the after-training test.

the greatest progress in the final SGT, showing that the shade guide matching exercise was the most effective. This was also confirmed by the enhanced correct matches in TST and reduced test times in SGT.

Among experimental groups, the most effective protocol was the 3D-Master training, which resulted in the greatest enhancement of correct matches, followed by Vitapan Classical and Basic colour training. These results may be explained as follows: in the 3D-Master section, participants were guided to analyse the colour of each shade tab logically in a three-dimensional manner, which improved their ability to determine the colours of the shade guides. This advantage has also been reported by other investigators; for example, its design was based on colour science (24). Moreover, it notably improved intra-rater repeatability among general practitioners (11). The superiority of Vitapan Classical exercise to Basic colour training was attributable mainly to the use of digital shade tabs, which were more similar to real shade tabs than the monochromatic rectangles in terms of shape and colour distribution. However, Vitapan Classical training mixed value and chroma exercise together in the low difficulty training, and shade selection was merely to choose a best-matched sample from a group of samples in the high difficulty level of training, which was not systematically enough. Thus, it should be used in conjunction with a more targeted training programme, such as Basic colour or 3D-Master training, to enable further improvements. The arrangement of Basic colour training was on the basis of hue and chroma in the three elements of colour. Each section was divided into matching and ranking two parts. The training was targeted and proceeded gradually in an appropriate sequence, thus improving colour analysis ability, but the shade tabs were quite different from natural teeth. Therefore, the effectiveness of individual training in terms of enhancing colour selection capacity was limited; and so Basic colour training should be combined with other training projects.

The time spent on the final test was almost identical to the baseline test in most groups, while other groups required less time after training. The reduction of test times occurred when the test was performed in a manner identical to the practice. This is consistent with a previous report (21).

There was no difference between TST and SGT in terms of correct matches or time required, suggesting the validity of digital shade guide tabs in representing the colour information of real shade guides. The previous study (21) also reported significant correlations between the two methods. An early study suggested that observers' shade-matching performance was significantly better with a digital than a conventional shade guide (25). However, the accuracy of the conventional group was relatively low (43%) compared with other studies. In the present study, 62·5% of participants reported differences between the digital and real shade guides. The reason was likely that the digital shade guides were photographs of real shade guides; they could not be exactly the same. Moreover, the two test methods were performed in completely different environments (under natural light vs. on a monitor). Based on this, the enhanced matching results in both tests are attributable mainly to improved colour-matching ability rather than participants having a memory of the shade tabs.

Subjective evaluations were important because they reflected participants' experiences with system and training protocols. The survey revealed that the system interface was user-friendly and easy to use, and all participants considered the training to be helpful. The self-confidence of participants was improved after training. Those who showed greater progress in the final test also exhibited better improvements in self-confidence, revealing that the objective and subjective evaluations were consistent.

Future research should include other training projects within the system, analyses of the potential effects of other factors and the arrangement of the training programme, in terms of achieving the greatest training effect. The system should be optimised and upgraded to extend its benefits to more dental students, and possibly also practicing clinicians.

Conclusion

Within the limitations of this study, the online colour training system represents a new, effective and efficient tool for colour teaching, particularly for dental students. Among the three system training methods tested, the Vitapan 3D-Master exercise was the most effective and efficient with better subjective evaluation. Use of the Vitapan Classical exercise and Basic colour training also resulted in improvements, but they need to combine with other methods to achieve optimal training effect. Shade guide training yielded the greatest improvement in 'Vita-Vita' test results. However, the higher cost and space restrictions associated with shade guide training may limit its popularisation.

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