Abstract: Perception of tooth shades is subjective and not rated exactly the same by different individuals. In terms of dental esthetics, chairside individualization of dental restorations might help to improve patient satisfaction. This investigation aimed to validate the practicability of a chairside approach for staining resin-based composite restorations. Thirteen inexperienced and 13 experienced participants were recruited to first individualize two CAD/CAM resin-based composite crowns in randomized order with light-curing characterization material using two reference crowns as templates. They then evaluated the characterization procedure. The processing times were recorded, and the clinical quality of the individualized crowns was evaluated by two blinded master dental technicians. Of the 52 crowns examined, 90.4% were assessed as suitable for insertion; there was no difference in quality attributable to the different degrees of experience of the operators. The average time required for characterization of the second crown was significantly shorter than for the first crown (30.9/43.0 min), indicating that the procedure can be implemented using a chairside approach. Among the operators, 80.8% said they would use the individualization technique and staining material again. Chairside staining of CAD/CAM resin-based composite restorations with light-curing characterization materials is practicable and can be recommended for both experienced and inexperienced users.

Keywords: cerec, color, esthetics, permanent dental restoration

Introduction

In dental practice, fabrication of fixed restorations is a popular approach for providing patients with esthetically pleasing tooth replacements within a single visit. All-ceramic restorations produced using a chairside approach are associated with high patient satisfaction, high survival rates and good clinical quality over long observation periods [1-4]. They can also be individualized in the direct presence of the patient using stains, thus facilitating highly esthetic results, since it has been shown that less than half of laboratory-fabricated restorations adequately match the adjacent natural teeth [5]. Moreover, the perception of color is very subjective and dependent on emotional sensitivity, suggesting that the rating of any individual restoration will not be exactly the same [Chu et al., Color in dentistry: a clinical guide to predictable esthetics, 12-14, Quintessence Publishing, 2017]. In this context, chairside individualization might help to improve patient satisfaction, adherence and acceptance of the newly inserted restoration.

Various manufacturers have provided instructions on the chairside staining procedure and a number of case reports have addressed this issue [6-9]. One disadvantage of staining dental ceramics is that subsequent glazing must be carried out, requiring additional equipment and time (about 25 min for glaze firing and cooling). Furthermore, differences in the mixing ratios of ceramic powders or frequent corrective firings can result in large variations of coloring and translucency [10,11].

In addition to ceramics, various resin-based composites are available as definitive restoration materials that can be used for computer-aided design/computer-aided manufacturing (CAD/CAM) [12]. Indirect resin-based composites have certain advantages in that restorations have high edge stability and low layer thickness; furthermore, introral repairs are simple since no hydrofluoric acid is needed [13,14]. In terms of esthetics, mono- and multilayer blocks are available and CAD/CAM resin-based composites can be characterized using a lab- and chairside approach with light-curing characterization materials. In comparison to ceramic materials, CAD/CAM resin-based composites are advantageous in that esthetic results can be achieved without additional firing, and only light-curing materials are needed (Figs. 1a, 1b). Thus, additional and expensive equipment is not required, and the time needed to finish the restoration can be minimized since no firing is necessary and the work can be done using only a conventional light curing unit. Although chairside staining of CAD/CAM resin-based composites is promoted by the manufacturers, to the authors’ knowledge no previous studies have validated the practicability of the technique in terms of processing time or the quality of the individualized restorations. Furthermore, no investigation has determined whether this technique can be used by inexperienced operators, or whether it can only be performed by experienced practitioners. As many dental nurses now individualize restorations fabricated using a chairside CAD/CAM approach, this issue appears to be of particular relevance.

The working hypothesis of the present study was that the degree of experience of the operator would not lead to any differences in the processing time or quality of the individualized CAD/CAM resin-based composite crowns.

Materials and Methods

In August 2018, 13 undergraduate dental students (inexperienced users) and 13 dental technicians (experienced users) were recruited to individualize a CAD/CAM resin-based composite for the first time (Grandio blocks H2 A2, VOCO, Cuxhaven, Germany). All users received the same one-hour lecture on the use of CAD/CAM resin-based composites and light-curing characterization materials; the latter were available in white, blue, yellow, orange, and brown (FinalTouch, VOCO). The inexperienced users were familiar with the handling of direct resin-based composites from one clinical course each in dental prosthodontics and preventive/operative dentistry. In addition, they had completed a two-hour hands-on course for staining of dental ceramics in the previous academic year. The experienced users had at least one year of professional experience.

Two crowns (#16 and #36) were fabricated and individualized by an independent dental technician prior to this study and served as characterization templates (Fig. 2). Each reference crown was stained in five areas according to the manufacturer’s instructions. The crowns were assigned to the operators in random sequence. During the staining process, the operators had access to the manufacturer’s information and the same working materials, and were instructed to characterize the crowns in accordance with the manufacturer’s specifications (Table 1). The processing time required for each individualization was recorded by an independent observer. At the end of the procedure, the participants were asked to complete an evaluation form in which they rated the processing time, application and polishing of the materials as well as their overall impression on a 5-point Likert scale (very good, good, sufficient, insufficient, poor). All data were collected in an anonymized manner so that two master dental technicians who were not involved in the characterization of the crowns were able to blindly assess the conformity of the quality in relation to the reference crowns using magnifying loupes. Shape, color, contamination, occlusion, polishing (one-step polishing system, Dimanto, VOCO), and overall impression of quality were rated using an evaluation sheet, and in the event of differ-
ing assessments, a consensus was reached by discussion. All crowns were evaluated within 5 h in the daytime (on the same day) in a room equipped only with north-facing windows. Crowns that received an overall impression of quality score of 1-3 (very good, good, sufficient) were considered to be clinically acceptable, and those with scores of 4-5 (insufficient, poor) as clinically unacceptable. Statistical evaluation of the collected data was carried out at a significance level of $P < 0.050$ (SPSS 22, IBM Corporation, Armonk, NY, USA). For comparisons of continuous data (age, processing time) the Shapiro-Wilk test for normality was used (all $P \geq 0.145$), and independent or paired $t$-tests were applied. For categorical data (scores) Mann-Whitney $U$-test (independent samples) or Wilcoxon signed-rank test (paired data) was used. The study was performed in accordance with the Declaration of Helsinki and all participants provided signed informed consent. As the participants received no intervention, and as no safety-relevant measures were performed, the Ethics Committee at the Medical Faculty of Leipzig University considered that no study approval was necessary. The waiver issued by the Ethics Committee was submitted to the Journal of Oral Science.

Results

The average age of the recruited participants (experienced and inexperienced) was $32.7 \pm 10.7$ years (min. 22 years, max. 60 years, 53.8% female). The distribution within the groups is shown in Table 2.
Characterization time

Comparison of the processing times among the users revealed a statistically significant reduction of $12.1 \pm 8.7$ min between the fabrication of the first ($43.0 \pm 12.1$ min) and second ($30.9 \pm 8.7$ min) crowns (Fig. 3) (paired $t$-test: both user groups $P < 0.001$). The experienced group showed a significantly shorter individualization time for the processing of both crowns than the inexperienced group (Table 2).

Quality of crowns evaluated by independent master dental technicians

The overall impression of the quality of the individualized crowns was rated at 2.6 by both user groups. In total, 90.4% of the crowns were assessed as being clinically acceptable for insertion. Shape and coloring were evaluated as being very good or good by 76.9% of the restorations, respectively. Contaminants on the individualized surfaces were observed in 9.6% of the crowns, and 42.3% of the polished surfaces showed inadequate (insufficient, poor) results (Fig. 4). There were no statistically significant differences in these criteria between the user groups in any category (Mann-Whitney $U$-test; all $P \geq 0.067$), nor were any significant differences identified between the evaluations of the first and second crowns (Wilcoxon signed-rank test; both $P > 0.193$).

Evaluation by the operators

The results of the questionnaire that was answered by the operators revealed that 80.8% of them would be prepared to use chairside characterization of CAD/CAM resin-based composite crowns in their everyday clinical practice; 19.2% said they would not consider it or would tend not to use it. The processing time was evaluated as very good or good by 80.8%, and 76.9% described the application of the characterization materials as very good or good. Polishing with the one-step polishing system was rated as very good or good by 80.8%, and 19.2% of them would be prepared to use chairside characterization (Wilcoxon signed-rank test: both $P < 0.001$). The experienced group showed a significantly shorter individualization time for the processing of both crowns than the inexperienced group (Table 2).

Discussion

To the authors’ knowledge, the present study is the first investigation to have addressed the practicability of chairside characterization of tooth-colored CAD/CAM resin-based composite materials. The overall impression of quality of 90.4% of the crowns was rated as clinically acceptable for insertion without further processing. The experienced users needed significantly less time than the inexperienced participants. These results partially refute the working hypothesis, since the processing time differed between the user groups; however, user experience had no influence on the quality of the individualized crowns. Moreover, a relevant effect of practice in terms of the time required for crown individualization was identified, indicating that the characterization technique has a steep learning curve. With regard to this aspect, the time required for the second individualization was clinically acceptable for both user groups, particularly in comparison with staining ceramics. Overall, application of the light-curing characterization material proved to be clinically acceptable.

While utilizing light-curing materials for characterization, a clean workstation is advisable in order to avoid contamination. The one-step polishing system applied to the fabricated crowns produced clinically insufficient results, suggesting that a multistep system should be used with low contact pressure. This recommendation has recently been included in the manufacturer’s instructions for the CAD/CAM resin-based composite and characterization material. Moreover, a recently published study has indicated that appropriate chairside polishing after intraoral adjustment as well as laboratory-based polishing after milling can produce CAD/CAM resin-based composite surfaces with similar roughness [15].

Due to the design of this study, the reference crowns could only represent a small variety of the esthetically challenging aspects of restorative dentistry, such as brown spots or discolored fissures. In daily dental practice, numerous characteristics would need to be considered; nonetheless, within the scope of the present study, the two reference crowns provided ten different types of modifications. Moreover, only one light-curing characterization system was evaluated, although many more are available such as Sinfony Magic for Lava Ultimate (3M, Seefeld, Germany) or OPTI-GLAZE color for Cerasmart (GC, Leuven, Belgium). As this study focused on practicability and handling of the individualization process depending on the operator’s experience, the characterization procedures were performed under standardized experimental conditions, including a single light-curing system and a room equipped only with north-facing windows. A comparison of different light-curing systems in future studies might be
interesting. Currently, the only case reports available are those describing chairside shading and staining of restorations with light-curing materials [7]. Future clinical trials (cohort studies, RCTs) will need to investigate the practicability of chairside characterization, especially in esthetically challenging areas such as incisor crowns in adolescent/young patients.

So far, no long-term clinical studies have investigated the performance of CAD/CAM resin-based composites. As some in vitro studies have indicated that composites might be influenced by aging and toothbrush abrasions [16-18] or might show discolorations due to food/drink [19], the color stability of characterized resin-based composite crowns in particular should be investigated.

Although there are data from in vitro studies addressing the mechanical properties of CAD/CAM resin-based composites [14,20,21], it is unknown whether staining, even if coated with direct resin-based composite materials, might affect certain properties such as hardness, surface quality or wear. This lack of knowledge might be the reason why some manufacturers (e.g. 3M [Lava Ultimate]) limit the indication of staining to pits and fissures. Future investigations, along with the present findings, might help to encourage chairside characterization in daily dental practice.

Chairside characterization of CAD/CAM resin-based composite restorations can be recommended as a technique suitable for both inexperienced and experienced users. With even brief training, inexperienced users can achieve processing times similar to those of experienced operators. However, for characterized CAD/CAM resin-based composite restorations, one-step polishing systems might yield clinically insufficient results.

**Table 3** Evaluation of the characterization materials for CAD/CAM resin-based composite crowns by operators (%)

|                         | Very good | Good | Sufficient | Insufficient | Poor |
|-------------------------|-----------|------|------------|--------------|------|
| Polishing               | 19.2      | 50.0 | 11.6       | 19.2          | 0.0  |
| Application             | 11.5      | 65.4 | 19.2       | 3.9           | 0.0  |
| Processing time         | 30.8      | 50.0 | 15.4       | 3.8           | 0.0  |
| Overall impression of operators | 11.6 | 26.9 | 42.3       | 19.2          | 0.0  |

**Fig. 4** Quality of crowns fabricated from CAD/CAM resin-based composites by inexperienced and experienced operators evaluated in consensus by two independent and blinded master dental technicians.

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**Conflict of interest**

The authors AR and SH declare that they have received funding for other studies from VOCO GmbH. The authors DG and OS declare that they have no conflict of interest. This study was not financially supported by a third party.
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