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Adhesive Management of Anterior Tooth Wear in Combination with the Dahl Concept—A 27-Month Observational Case Series

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Clinical Relevance

Localized anterior tooth wear can be restored with adhesively bonded labial ceramic and palatal direct resin composite veneers at an increased vertical dimension of occlusion. This additive technique provides maximal tooth preservation for a worn dentition.

SUMMARY

Localized anterior maxillary tooth wear caused by erosion and attrition with loss of interocclusal space is difficult to manage.

This observational case-series study reports six cases with worn anterior dentition treated with labial ceramic and palatal direct resin composite veneers at an increased vertical dimension of occlusion without restoration of unaffected posterior teeth.

Thirty-six palatal direct veneers were made in six patients from a nanohybrid resin composite with the help of a wax-up-based template at an increased vertical dimension. After the complete re-establishment of posterior occlusion, 40 labial lithium-disilicate ceramic veneers were fabricated with a mock-up-guided method. The sandwich veneers were evaluated according to the United States Public Health Service (USPHS) criteria after a mean service time of 22.7 months. Re-establishment of posterior contacts as well as subjective patient satisfaction and function were evaluated. The overall success of the labial ceramic veneers was excellent. The quality of the palatal resin composite restorations was found to be good with predominantly "Alpha" scores. The marginal quality (11.1% and 33.3% of integrity and discoloration, respectively) and surface roughness (16.7%) showed small deteriorations indicated by "Beta" scores. The resin composite showed, in general, signs of wear facets which resulted in "Beta" scores in 44.4% of the cases. Posterior contacts re-established firmly within 4 weeks in all cases. Patient satisfaction with esthetics and function was high. The short-

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term outcome of this non-invasive treatment option is favorable and promising.

INTRODUCTION

The general term for non-carious tooth loss is tooth wear and describes loss of dental hard tissue that can be generated by different etiological factors such as chemical and mechanical processes.[1] According to Loomans and others, tooth wear is pathological if it is atypical for the age of the patient or causes pain or discomfort, functional problems, or deterioration of esthetic appearance; if it progresses, it may give rise to undesirable complications of increasing complexity.[2] Tooth wear can be identified as erosion, attrition, abrasion, and abfraction.[3] Clinical observations have demonstrated that wear mechanisms do not act alone but instead cause loss of tooth surfaces by interacting with each other.[4] An increased incidence of erosive wear is being reported in young populations thanks to their dietary habits, the increased consumption of soft drinks and energy drinks, and the stressful effects of an accelerated lifestyle.[5] Irrespective of etiological factors, tooth wear can influence oral health and personal comfort and may result in loss of vertical dimension of occlusion (VDO) and in tooth sensitivity and pulpal involvement. However, especially for young adult patients, esthetic complaints are paramount.[6,7] Also, depending on the progression of tooth wear, incisal edges may show signs of wear and shortening due to loss of enamel support and subsequent chipping. The rate of anterior erosive tooth wear can be severe, even at an early age, if bruxism or other parafunction occurs alone or concurrently with erosion.[8]

The management of tooth wear may involve complex preventive and restorative care, possibly with full rehabilitation at an increased vertical dimension of occlusion.[9-11] Currently, adhesive dentistry is undergoing considerable progress, enabling advanced restoration techniques. In the restorative management of tooth wear, there has been a tendency towards minimum-intervention approaches.[2] Following the minimally invasive treatment concept, partial-covering, all-ceramic restorations and direct–resin-based composite (RBC) have recently become recommended as preferred therapy.[12-16] Mesko and others included several papers in their systematic review of the materials and techniques used to restore teeth with severe tooth wear.[17] They concluded that the absence of randomized clinical trials on the subject appears to be the main limitation of the existing evidence. However, in line with Ahmed and others, Mesko and others also found RBC to be a feasible option to restore teeth with severe wear and demonstrated good performance of this material over short- and medium-term follow-up.[17,18] Unlike the traditional subtractive techniques, RBC, with the help of reliable adhesion to the tooth, provides additive treatment solutions while preserving the remaining tooth structure.[2] Vailati and Belser presented a three-step technique to reconstruct eroded anterior teeth with an additive adhesive approach, providing maximum preservation of tooth structure with a predictable esthetic and functional outcome.[19-21] The applied sandwich veneers provide palatal guidance and buccal esthetics with the protection of the remaining tooth structure as well as adhesive increase of VDO in the molar region.[19-21]

An ultraconservative and simplified treatment is proposed, using the combination of centric relation and the Dahl principle in the solution of localized anterior tooth wear and erosion.[22] In localized anterior tooth wear, compensatory eruption may take place, maintaining the VDO despite the loss of anterior clinical crown height.[23] The resultant loss of interocclusal space presents a challenge for restoration, especially when the posterior teeth are unaffected. The Dahl approach consists of creating interocclusal space through axial tooth movement, with an appliance or restorations placed in supraocclusion, and the subsequent re-establishment of full arch occlusal contacts over a period of time.[24,25] The original Dahl appliance was based on a metal cobalt-chromium appliance cemented on the palatal surfaces of upper anterior teeth; however, more recently RBC restorations have been used to create the space with good short- to medium-term survival.[25-28] Although the clinical performance seems satisfactory, the limited mechanical and physical properties of RBC restorations demand maintenance.[28] To overcome the esthetic issue that arises from the deterioration of RBC, ceramic veneers can be used on the labial surfaces of anterior teeth, following the perceived needs and concerns of the patient. Meanwhile, the RBC on the palatal surface can withstand the increased functional stress at an increased VDO. At the level of case reports, this sandwich approach, in combination with the Dahl principle, was introduced by Magne and others, but there is a lack of data about the short-, medium- and long-term performance of this biomechanically favorable treatment option.[22]

The aim of this prospective, observational case-series study was to assess the short-term clinical performance and patient satisfaction associated with

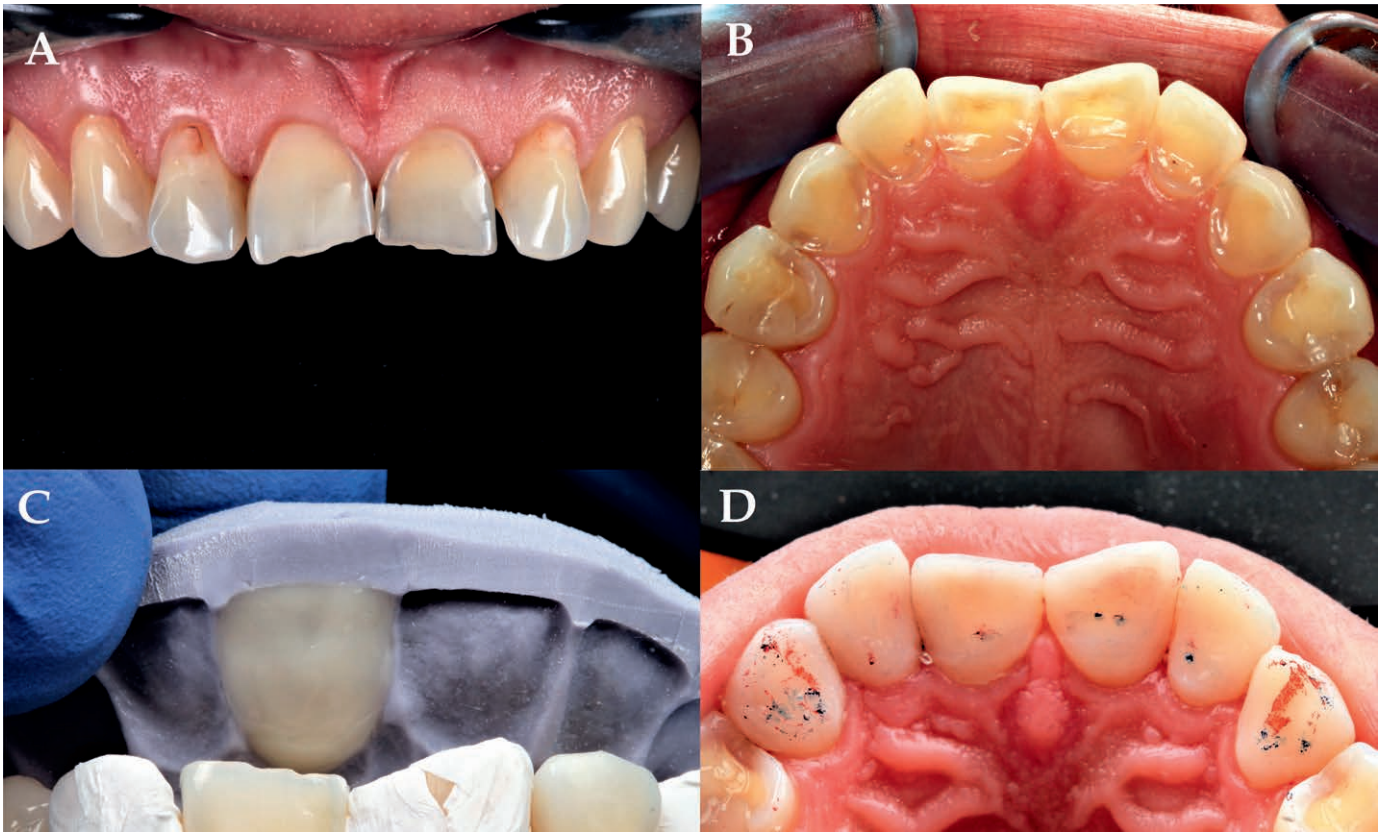

Figure 1. *Initial situation of localized anterior tooth wear from labial (A) and palatal (B) aspects. The process of the palatal direct resin composite veneer fabrication by silicone matrix technique (C) providing static and dynamic contacts on the anterior teeth (D).*

a sandwich approach to the treatment of localized anterior tooth wear, consisting of palatal resin composite direct build-ups and vestibular lithium-disilicate veneers in combination with the Dahl approach.

METHODS & MATERIALS

Patient selection

For this prospective, observational case-series study a total of six patients (two males and four females) aged 22 to 34 years were selected according to predetermined inclusion criteria. All participants were required to be adults able to read and sign the informed consent document and to be physically and psychologically able to tolerate the procedure. In addition, patients selected for the study needed to have good oral hygiene, full dentition, and normal occlusion and to be without periodontal disease, as verified by clinical and radiographic records. Moreover, patients were required to remain in continuous clinical follow-up without attending other dentists. The minimal length of the follow-up period was 20 months. Reasons for placement of direct palatal RBC veneers and labial ceramic veneers were either localized anterior attrition or combination of erosion and attrition with relatively unaffected posterior teeth (Figure 1A, 1B). Tooth wear was determined to be clinically significant when dentin was exposed and when there was a reduction of crown height. Margins placed on enamel with a vital pulp were also required for the placement of direct and indirect veneers.

The patients were seeking advice for esthetic reasons, to improve their deteriorated and socially disadvantageous smiles. Before the written informed consent was signed, patients were given a full explanation of the proposed treatment. They were treated at the Operative Dentistry Department of the University of Pécs by one operator. The cause of the localized anterior tooth wear was identified as closely as possible, based on a careful history and examination. The etiology was primarily attrition (bruxism-related occlusal stress) in half of the cases and combined erosion/attrition (confirmed and treated gastroesophageal reflux disease in two cases and a high rate of soft drink/energy drink consumption in

one case with concurrent bruxism-related wear) in the other half (Table 1).

Bruxism-related occlusal stress was identified by self-report and clinical examination. The etiology of bruxism related to anxiety, insomnia, and lifestyle-related stress. Elimination of the etiological factors was being started or was ongoing.

History taking was performed by a questionnaire survey developed by Pintado and others that focused on nocturnal or awake tooth grinding, jaw fatigue, or temporal headache on awakening.[29] The clinical examination consisted of the assessment of tooth wear, chipping, or abfraction, masticatory muscle hypertrophy or discomfort, tooth mobility, hypersensitivity, clicking of the temporomandibular joint, and tongue or cheek indentation.[30] Before the start of treatment, patients were provided a consultation with an expert in temporomandibular disorders. The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) were clinically applied to determine the presence or absence of any temporomandibular disorder.[31,32] The erosive status of the maxillary anterior teeth was evaluated with the help of the Anterior Clinical Erosive Classification (ACE).[33] Localized anterior loss of tooth structure, including dentin, with minimum wear of mandibular incisors, relatively intact posterior occlusal surfaces, and absence of temporomandibular disorder were diagnosed from the clinical examinations. According to self-reports and clinical signs, all the patients suffered from bruxism-related occlusal stress. Table 1 shows patient-related factors such as age and gender and provides information about the etiology and classification of tooth wear.

The suggested therapy, approved by the patients, was the sandwich veneer approach in combination with Dahl's concept. Patients received a total of 36 direct palatal RBC veneers on their vital maxillary anterior teeth (Table 1). This method can replace the eroded tooth structure with an additive approach at an increased VDO. The residual posterior interocclusal space is progressively eliminated by the passive eruption of the posterior teeth and the slight intrusion of the anterior teeth, reestablishing the occlusal contacts. A total of 42 lithium disilicate-reinforced pressed ceramic veneers were used on the labial surfaces to improve esthetic appearance and maximally preserve the remaining tooth substance while simultaneously balancing the functional stresses on the anterior dentition (Table 1).

Restorative Procedure

Upper and lower one-stage sandwich vinyl polysiloxane impressions (Variotime Easy Putty and Light Flow, Kulzer, Hanau, Germany) were taken. This was followed by bite registration (Variotime Bite, Kulzer) recorded in centric relation obtained by a leaf gauge. The difference between maximal intercuspation and centric relation was also determined. A facebow was used to transfer the relation between the jaws and temporomandibular joint. The study casts were then mounted on an articulator in centric relation. A wax-up was carried out on the palatal, incisal and labial surfaces of the upper six anterior teeth and additionally on the labial surfaces of those premolars which were affected by the erosive effect. The wax-up was the basis for creating an intraoral mock-up (Structur 2 SC, VOCO, Cuxhaven, Germany), which was used as a visual aid to show the proposed treatment outcome and analyze the esthetic and functional (anterior and canine guidance) changes. A silicone mold (Registrado Clear, VOCO, Cuxhaven, Germany or Variotime Easy Putty, Kulzer, Hanau, Germany) from the diagnostic wax-up was used as a trimmed palatal/incisal stent for the direct RBC build-ups to provide a desirable form for the palatal surface. Before the build-up procedure the teeth were isolated with a rubber dam and the palatal surfaces of the anterior teeth were air abraded with 29 μm Al_2O_3 powder with copious irrigation at 1 mm distance for 15 seconds (Aqua-Care Twin, Velopex, London, UK). Only sharp enamel edges were removed with a diamond bur (No.890LF, Meisinger, Neuss, Germany). To prevent bonding to adjacent teeth, every second tooth was restored at the same time. Teeth were separated with slight interproximal stripping (Sof-Lex Finishing strips, 3M, St. Paul, MN, USA) and isolated interproximally by a Teflon (DuPont de Nemours Inc, Wilmington, Delaware, USA) tape. Regarding the adhesive technique, a two-step etch-and-rinse system (Adper Single Bond, 3M) was used for each restoration. Every second tooth was conditioned with the etch-and-rinse technique by applying 37% phosphoric acid for 20 seconds (Ultra-etch, Ultradent, South Jordan, UT, USA), followed by 20 seconds of rinsing and careful drying. The one-step enamel-dentin adhesive was applied by rubbing the exposed dentin and enamel with a micro-brush soaked in the resin. In order to evaporate the solvent, gentle, 10-second air-drying was carried out, followed by 10 seconds of polymerization with a light-emitting diode (LED) curing unit (LED.D, Woodpecker, Guilin, China; λ = 420–480 nm) in standard mode, at an

average tip irradiance of 1450 mW/cm^2 with an 8 mm diameter fiberglass light guide. Nanohybrid RBC (Enamel Plus HRi Bio Function, Micerium SpA, Avegno, Italy; BF2 shade) was applied to the matrix in alternating order; then the matrix was seated on the teeth and the excess material was removed from the labio-incisal aspect, maintaining the planned new length as seen with the help of the stent (Figure 1C). The RBC was light-cured for 40 seconds from an incisal direction. After removal of the stent, the palatal surface was directly light cured for a further 40 seconds to provide a high rate of polymerization. Interproximal excess was removed carefully, without causing bleeding, with a metal interproximal strip (Kerr perforated fine diamond finishing strip, Kerr, Bioggio, Switzerland). The restorative procedure was repeated for the remaining teeth. Once all the teeth had been bonded to the palatal aspect, the labio-incisal surface was covered with one more layer of RBC to provisionally complete the anterior restoration at the desired length until the posterior contacts were re-established. The provisional increase in length with direct RBC provided a functional test for the re-established anterior and canine guidance. Patients were informed about possible inconvenience that could be caused by the posterior disclusion and the color mismatch of the lengthened incisal edge before the final facial veneer fabrication. The finishing-polishing procedure was performed with football, needle shape red fine-grit diamond burs (330F and 890LF, Meisinger, Neuss, Germany) followed by the Enhance/PoGo system (Dentsply Sirona, York, PA, USA) and aluminum oxide strips (Sof-Lex Finishing strips, 3M). Then the occlusion was refined to ensure even, stable contacts on all anterior teeth of equal intensity in centric relation (static occlusion) and guidance provided by the incisors and canines (dynamic occlusion) (Figure 1D). The occlusion was developed according to the following principles: The restored palatal surface and the increased incisal length must be in harmony with the envelope of function and should provide unobstructed movement. The palatal cingulum and slightly flat occlusal stop provide stable contact and centric freedom for the lower incisors. This smooth surface helps minimize future wear of the opposing lower incisors and directs forces down the long axis of the tooth, thereby reducing possible labial tooth movement. During lateral excursion the canine guidance should provide incisal disclusion, which is crucial to avoid future fracture of the restored incisal edges. After the occlusal adjustment, final finishing and polishing were performed by the Enhance/PoGo system and surface gloss was enhanced by goat hair brush, felt disk/wheel and polishing pastes (Enamel Plus HFO Shiny Finishing Kit, Micerium SpA). Posterior disclusion was measured from a wax record taken postoperatively between the first molar teeth (Table 1). The increase of VDO by the additional palatal layer ranged between 1.0 mm and 2.0 mm.

Two to three days after the palatal restorative procedure, patients were scheduled for an anterior occlusal check-up to control the stable contacts and anterior guidance. The investigators also considered it important to assess patient comfort and to test the phonetic implications of the extensive rehabilitation of the maxillary incisors. For a phonetic test, the "s" sound was used, since it can be influenced by horizontal or vertical volume alterations of the anterior teeth.

Progression of posterior tooth eruption was assessed weekly with an 8 μm Shim Stock foil (Arti-Fol, Bausch, Köln, Germany) (Figure 2A-D). After the detection of firm contacts on all posterior teeth (four weeks after palatal build-up for all patients) the procedure for labial ceramic veneer fabrication was begun. The first step was the mock-up preparation based on the initial diagnostic wax-up. As the new position of the occlusal plane and the increased VDO may be slightly different from what was initially planned, the length of the maxillary anterior teeth needed to be reconfirmed during this second mock-up session. Once the patient's agreement with the final shape of the maxillary anterior teeth was obtained, the mock-up guided preparation was performed with the help of a depth-marker diamond cylinder bur (No.834, size 016, cutting depth 0.3 mm; size 021, cutting depth 0.5 mm; Komet, Besigheim, Germany) (Figure 3A). Three shallow orientation grooves were cut through the mock-up RBC and/or enamel on the labial surface. Then the mock-up was removed and the mark on the enamel left by the orientation groove was highlighted with a water-resistant pen (1513 Multimark F permanent, Faber-Castell, Stein, Germany). Round-ended tapered diamond burs (No.868 and 8868, Komet, Besigheim, Germany) were used to remove enamel between the marked grooves and to create definitive contouring and finishing. The color marking was not removed completely, to ensure that no more than the desired enamel was prepared. A supra/paragingival chamfer-like finishing line was prepared at a depth of 0.3 mm; this was extended interproximally as an elbow, involving the labial half of the contact area without breaking the contact. A butt-joint incisal preparation was performed, completely removing the length

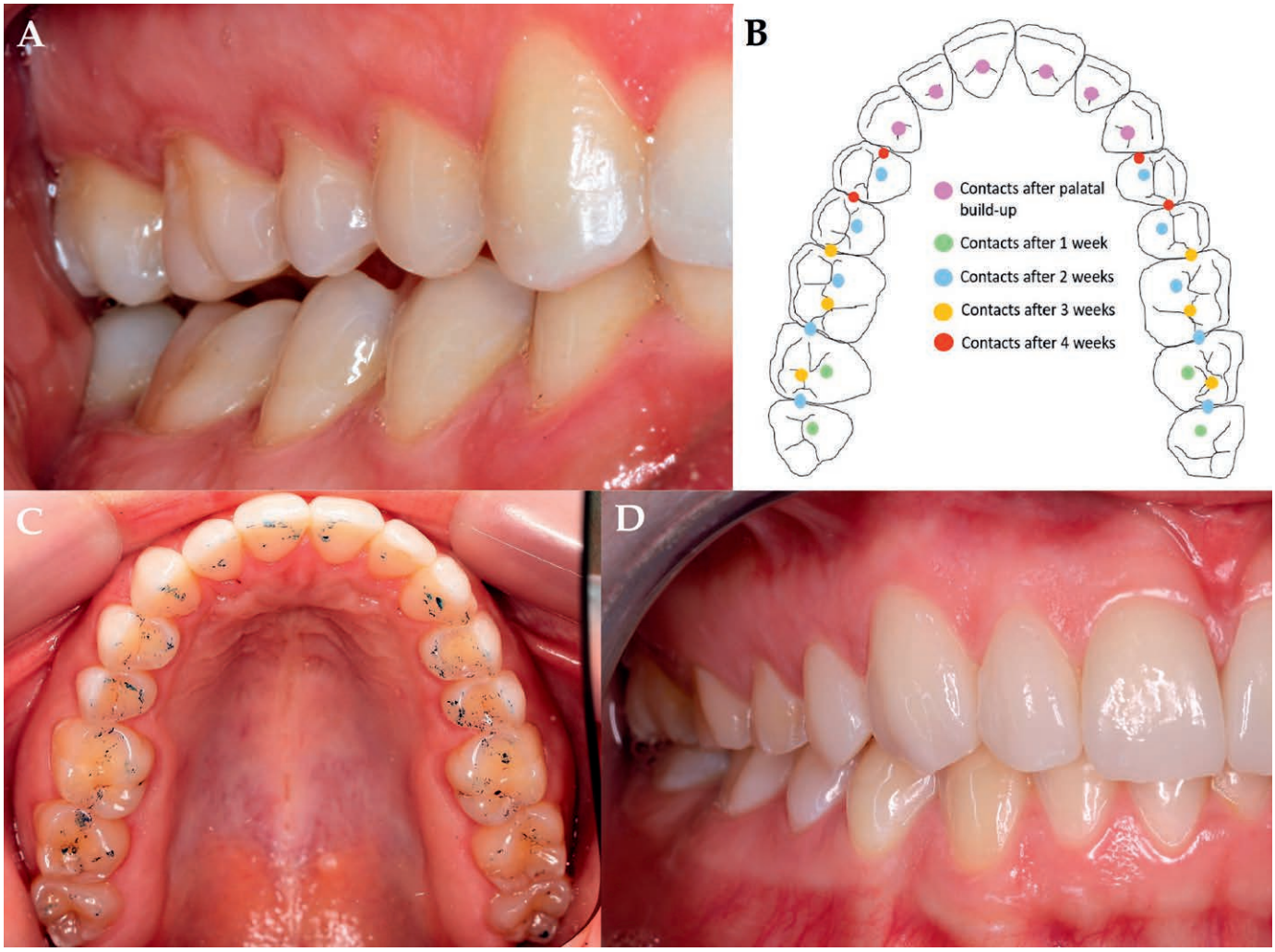

Figure 2. *The initially discluded posterior teeth (A) showed a general progression of eruption (B), resulting in firmly re-established posterior contacts (C, D).*

added by the provisional RBC build-up, leaving only the original length of the tooth (Figure 3B). The ceramic veneer would later re-establish the final length. The margin was placed in the volume of the palatal RBC (Figure 3B and Figure 4A-C). The prepared surface was polished with abrasive discs (Sof-Lex disks, 3M) and a gingival retraction cord (0, UltraPak, Ultradent) was placed in the sulcus. Upper two-stage and lower one-stage sandwich vinyl polysiloxane impressions (Variotime Easy Putty and Light Flow, Kulzer) were taken. This was followed by bite registration (Variotime Bite, Kulzer) recorded in maximum intercuspation. The shade of the prepared teeth and also the desired shade were selected with the patient's agreement. Provisionals were made with the help of the impression that was fabricated to perform the mock-up. At the next appointment the pressed lithium disilicate-reinforced glass-ceramic laminate veneers (GC Initial LiSi Press, GC, Leuven, Belgium) were placed in the mouth to check the fit, and try-in paste (NX3 Nexus Third Generation, Kerr) was used to select the proper shade of the adhesive luting cement (Figure 3C). To achieve durable bond-strength the internal surfaces of the cleaned (Ivoclean, Ivoclar Vivadent, Schaan, Liechtenstein) veneers were etched with 9.5% hydrofluoric acid (Porcelain Etch, Ultradent) for 20 seconds, followed by washing, drying and silane (Silane, Ultradent) application which was left to dry. The luting procedure was started with both cleaned central incisors and progressed bilaterally. The above-described total-etch adhesive procedure was performed on the isolated teeth. To provide accurate fit of the veneer prior to light-curing, the adhesive layer was thinned with air-drying for a minimum of 20 seconds; the removal of excess was

Figure 3. *Indirect ceramic veneer fabrication with mock-up guided preparation (A) with butt-joint incisal finishing line (B). Try-in paste helps to select the favorable shade of the adhesive cement (C) to provide a natural appearance for the veneers (D).*

aided by the vacuum of the high-volume evacuator tip. A clean microbrush was used to remove the gathered excess at the marginal bevel if the effects of the air-stream and the evacuator needed to be completed. Light-curable adhesive resin cement (NX3 Nexus Third Generation, Kerr) was applied to the veneers, which were then gently seated with finger pressure. Excess cement was removed with a microbrush and a thin modelling brush. The above-mentioned LED curing unit was used to polymerize the cement for 4 × 20 seconds from labial, mesial, distal, and incisal aspects with 5-second breaks to avoid heat damage to the pulp. The final restorative phase was completed by polishing the marginal areas with a silicone rubber point (PoGo system, Dentsply), after removal of excess set cement with a #12 surgical scalpel (Figure 3D). Restorations were carefully checked for any occlusal interference (static and dynamic). After the one-week follow-up of the labial veneers, maintenance was provided in each half year.

Clinical Evaluation

From the palatal build-up session, the progression of the compensatory eruption was recorded weekly by the evaluation of the opposing contacts until maximum intercuspation was achieved between each posterior tooth. At the five-week follow-up appointment, the patient's opinion on the esthetic result, post-operative pain or discomfort, and bruxism or TMD-related symptoms were evaluated (Table 2).

In January of 2020, the anterior palatal direct RBC veneers and labial ceramic veneers were evaluated by two examiners independently, using a dental mirror and explorer in accordance with modified USPHS[27] criteria (Table 3). Particular attention was paid to the interface between the

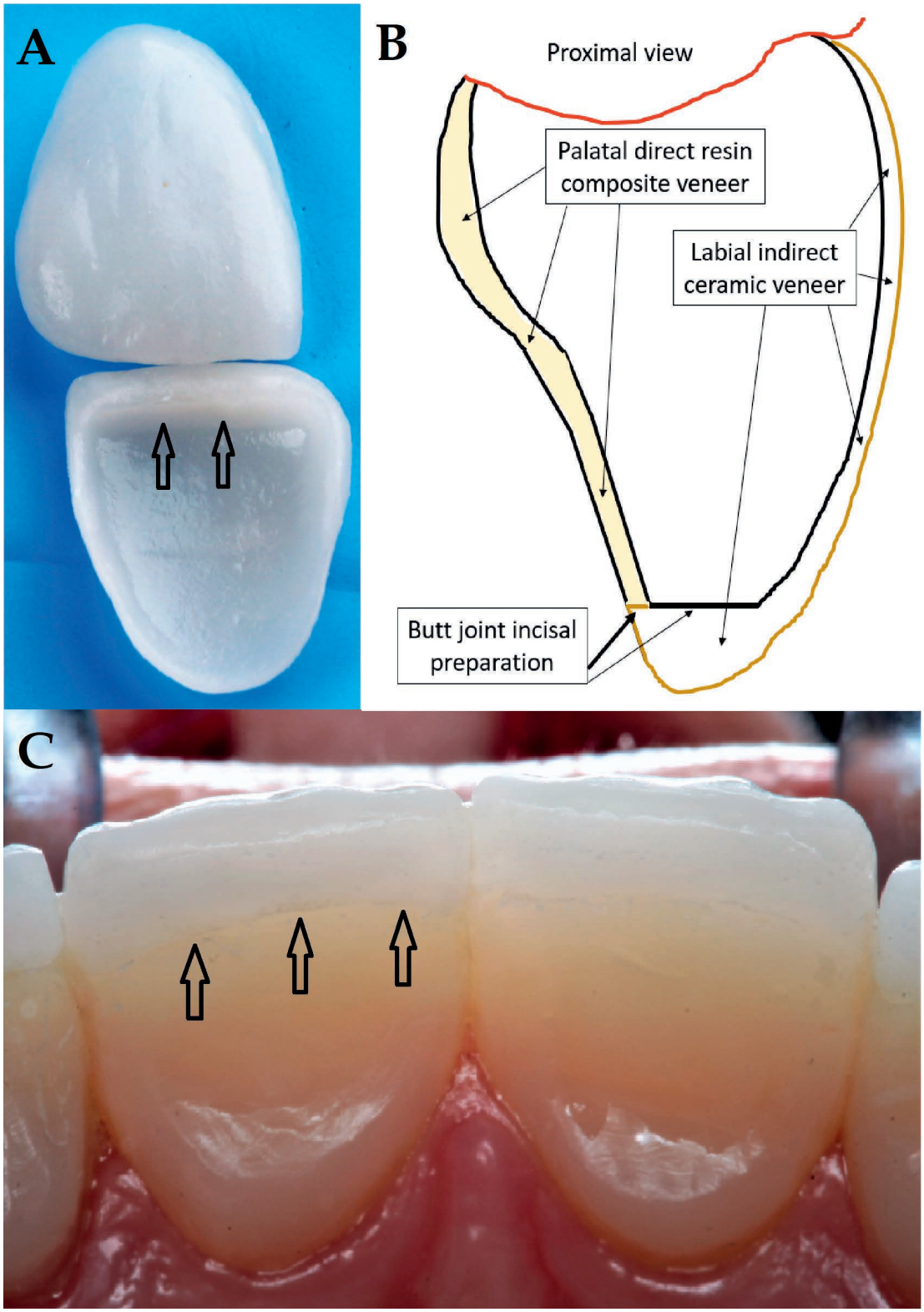

Figure 4. *Butt-joint incisal preparation is well seen on the veneer in-surface (arrows) (A), which is seated onto the plane-cut incisal edge including the palatal direct resin composite veneer (B), leading to a palatal-labial veneer interface located on the palatal veneer margin (arrows) (C).*

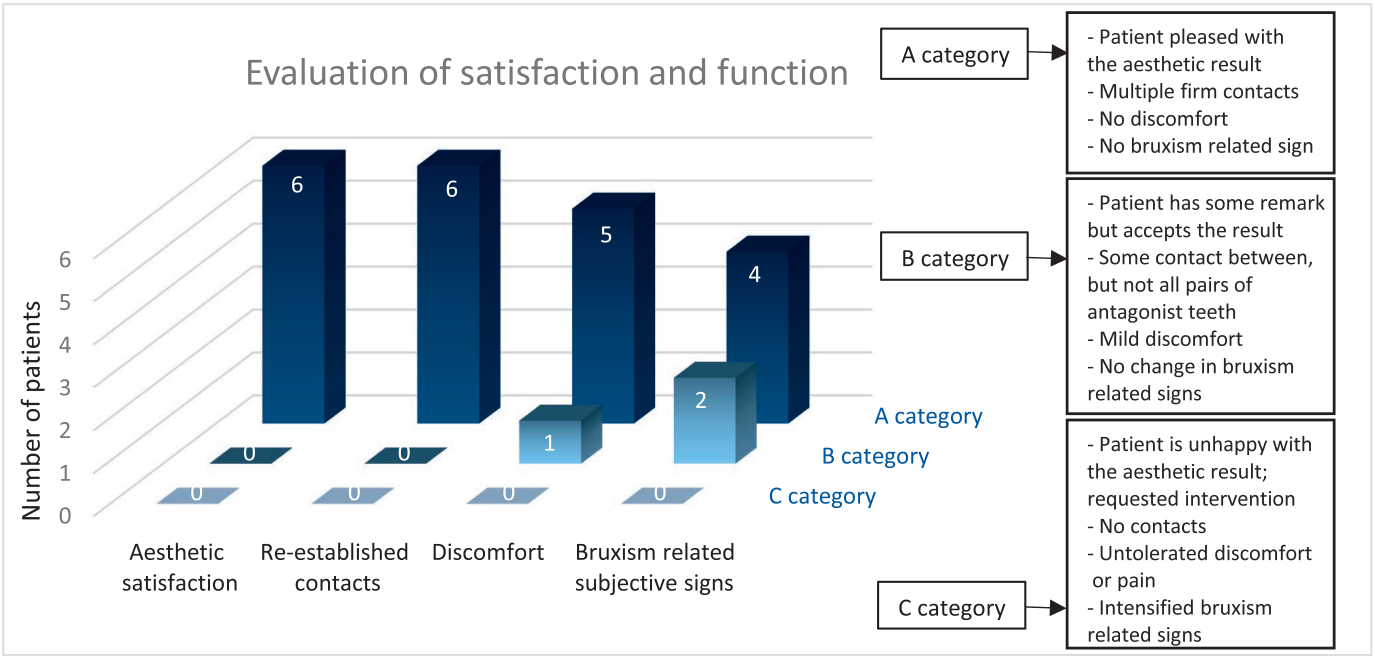

Figure 5. *Evaluation of patient satisfaction and function.*

palatal direct veneer and the labial indirect veneer in terms of marginal integrity. The time and type of any intervention applied during this maintenance examination were recorded, and patients were questioned again about their esthetic satisfaction, discomfort, and bruxism or TMD-related symptoms.

Data collection and statistical analysis were performed using SPSS for Windows 23.0 (SPSS, Chicago, IL, USA). Because of the low case number, only a descriptive statistical analysis was indicated and only percentages of the respective scores of the USPHS evaluation are given.

RESULTS

In the present observational case-series study a total of 36 direct RBC palatal veneers and 42 labial ceramic veneers were evaluated in six adult patients (mean age: 26.67 at the time of restoration placement) with the diagnosis of localized anterior tooth wear. The follow-up time varied from 20 months to 27 months for palatal veneers and 18 months to 25 months for labial veneers, with a mean observation time of 23.7 and 21.7 months, respectively. The investigators were trained and calibrated before the evaluation. Cohen's kappa statistic showed excellent intraobserver (kappa values of 0.82 and 0.80) and interobserver (kappa value of 0.79) agreement. Figure 5 shows the evaluation of patient satisfaction with the esthetic result, discomfort, re-establishment of posterior contacts, and bruxism- or TMD-related symptoms at the five-week (from the palatal build-up to one week after the labial veneers were cemented) follow-up appointment. According to one participant's report, discomfort was only present in the first few days after the palatal build-up. Phonetic alterations—in pronouncing the "s" sound—occurred for all patients, but after a short conversation (five- to ten-minute adaptation), it was no longer perceptible. The progression time and order showed almost the same pattern for all participating patients, as shown in Figure 2C. All patients accepted the new VDO well, without showing symptoms of TMD. However, bruxism was still present in two patients (by self-report), although it had not intensified. To decrease the risk of bruxism-related failure, supplemental protection with a night-guard (Michigan-type occlusal appliance) was fabricated for the above-mentioned patients at the five-week check-up (Figure 6). During the subsequent observation period there was no change in esthetic satisfaction, and the stabilized occlusion was reported to be comfortable. Based on the self-reports and clinical examinations of the other four patients, there were no obvious signs of bruxism, despite its being present at the start of treatment. The evaluation, following the USPHS criteria, of the palatal direct RBC and labial ceramic restorations is presented in Figure 7; this evaluation also involved the assessment of the marginal adaptation

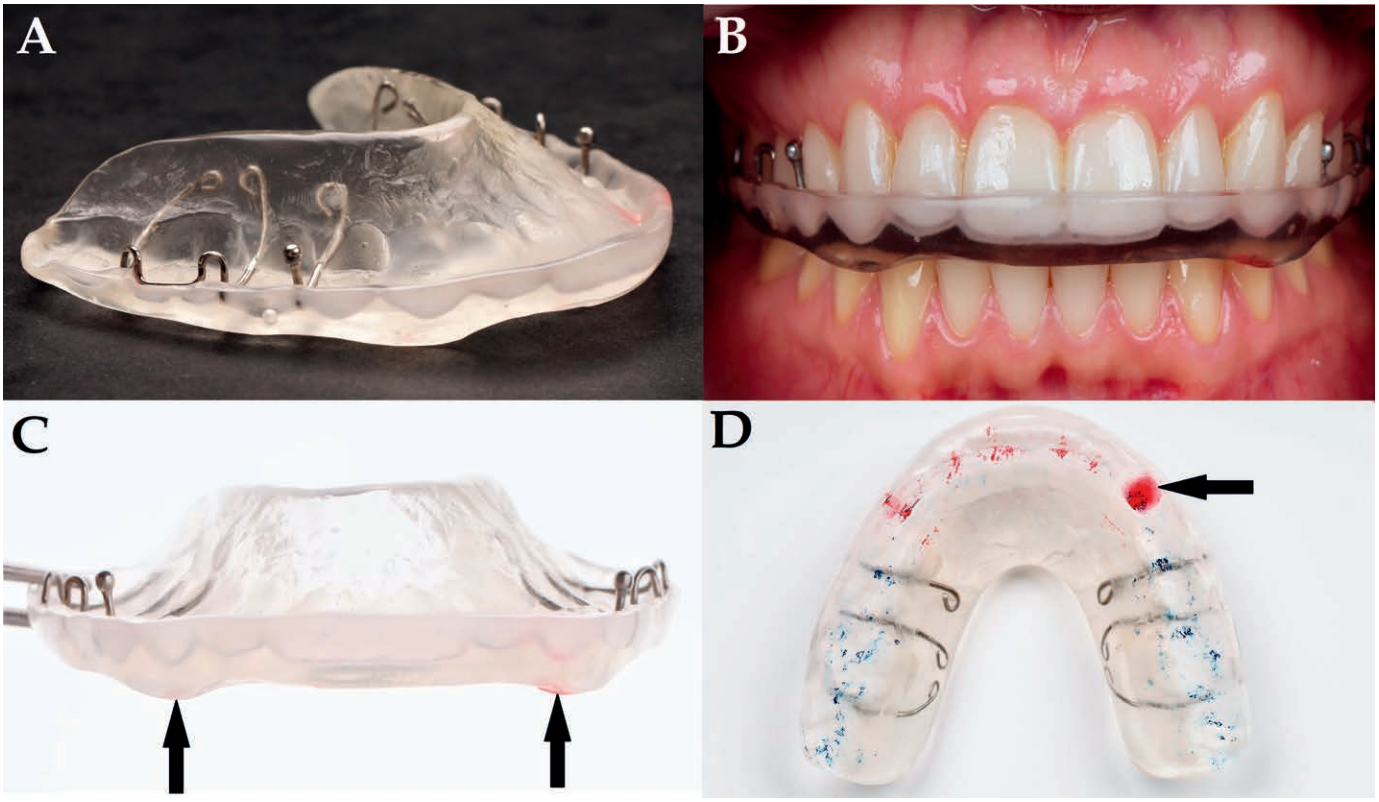

Figure 6. *Michigan-type occlusal night-guard splint is fabricated in hard transparent thermoplastic polymer (A) that covers all the maxillary teeth (B) and has flat, simultaneous occlusal centric stops for mandibular teeth. The sloping canine guide plane (C – black arrows) of 1 to 2 mm permits only minimal lateral or protrusive movements under full occlusal contact (D – blue marks) of the lateral splint surface before disclusion occurs. Anterior and canine guidance (D – red marks) provides posterior disclusion. Thin layer of pattern resin was used chair-side to correct the canine guidance on the left side (D – black arrow).*

and discoloration of the palatal-labial veneer interface. During the observation period, all the involved teeth were caries-free and remained vital. Of the overall 78 restorations, none were considered unacceptable; the restorations were scored as "alpha" or "bravo" for all items evaluated according to the USPHS criteria. The survival for both types of restoration during this short-term observation period was 100%. Palatal direct restorations had higher rates of small deteriorations for almost every evaluated criterion (Figure 8A), except for anatomic form and color match. Slight wear on the palatal restoration was found to be the most frequent issue (44.4%), followed by slight marginal discoloration (33.3%). Pitted surface roughness was found on all six palatal RBCs (16.6%) in one patient, whereas the texture of all other palatal veneers showed a silky gloss appearance. Slight marginal deterioration was detected in only four palatal veneers (11.1%), which were managed with repolishing. The labial-palatal veneer interface showed mild deterioration in marginal adaptation (16.7%) and marginal discoloration (22.2%). The labial ceramic veneers showed excellent performance, with slight marginal discoloration detected at only one veneer (Figure 8B).

DISCUSSION

In this prospective, observational case-series study the short-term survival of anterior sandwich veneers performed as Dahl-restorations was evaluated in six patients who suffered from localized anterior erosion and/or attrition. In addition, patient satisfaction, discomfort, progression of posterior tooth eruption, and bruxism-related occlusal stress were also analyzed. Acceptable-to-excellent clinical performance was observed for the sandwich veneers, which consisted of direct palatal RBC and indirect labial ceramic restorations, after a mean observation period of 23.7 and 21.7 months, respectively. However, results and survival analysis should be interpreted with care because, on one hand, the case number is very limited, and on the other, no long-term data are available regarding this sandwich veneer approach. Our primary purpose was not only to describe the outcome of the

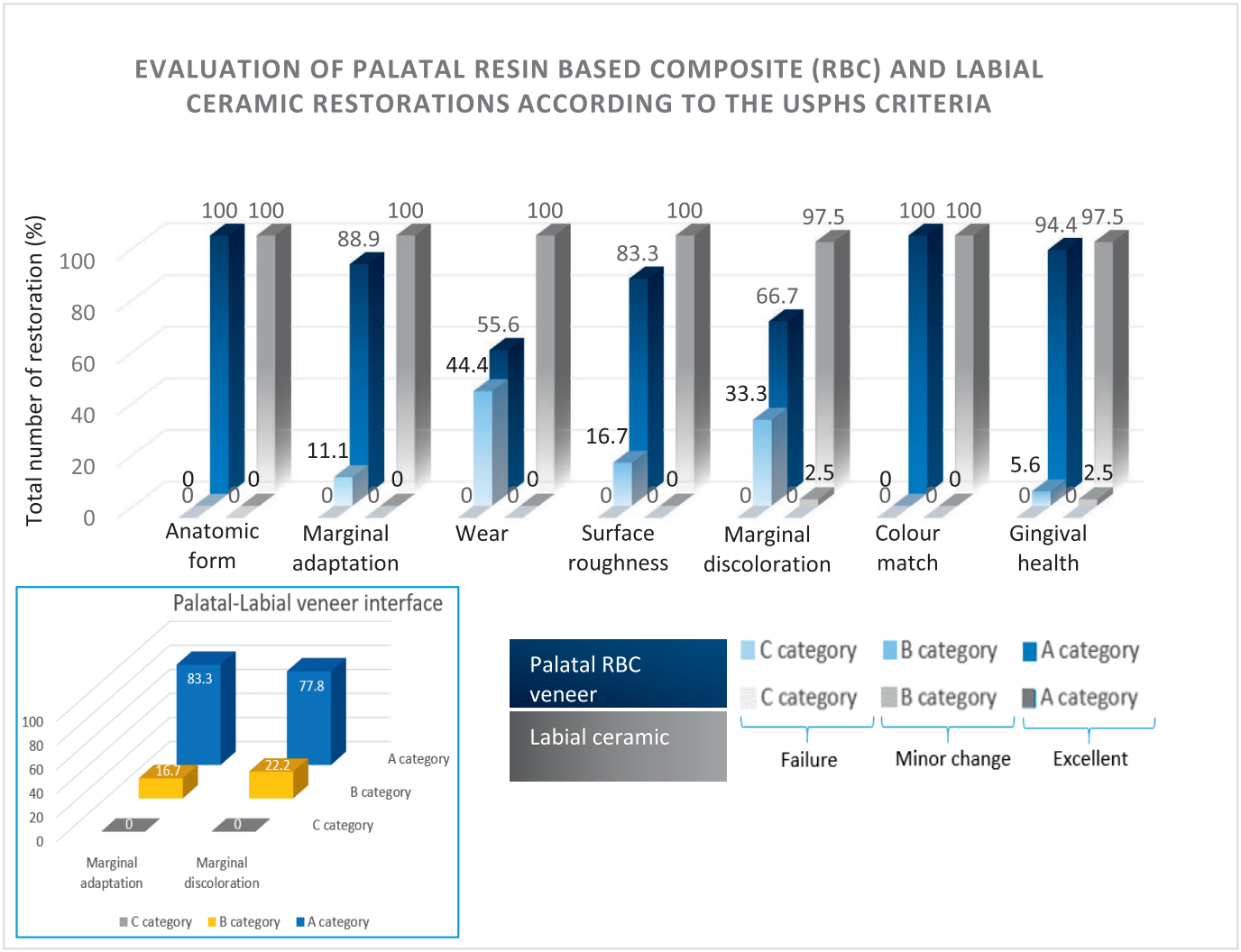

Figure 7. *Evaluation of palatal resin-based composite (RBC) and labial ceramic restorations according to the USPHS criteria.*

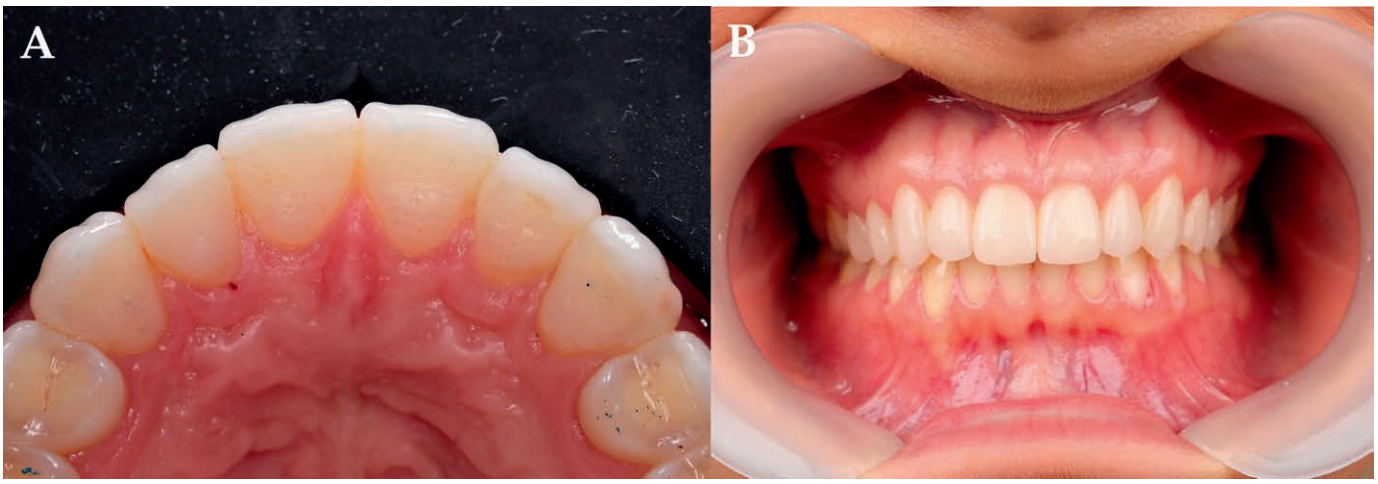

Figure 8. *Slight discoloration of the margins and pitted surface roughness of the palatal veneers is detectable (A); however, the labial ceramic veneers were excellent (B) at the 23-month follow-up appointment.*

sandwich approach after a short observation period, but also to generate hypotheses that can be tested subsequently, in studies of greater methodological rigor, regarding the survival of this treatment method.

Vailati and Belser introduced a three-step adhesive rehabilitation technique with a minimally invasive sandwich approach that reconstructs the palatal surface first with direct or indirect resin-composite palatal veneers followed by the restoration of the labial aspect with ceramic veneers.[19,21] This adhesive technique allows preservation of the remaining tooth structure, especially with respect to the intact proximal surface. In a 6-year follow-up study, the authors' subsequent work demonstrated no major detectable failure of sandwich restorations.[34] Adhesively bonded ceramic veneers with well-planned surface treatment and cementation protocol represent a highly reliable esthetic and functional long-term treatment option and is supported by several other studies.[35-38] Due to the low number of cases, our results cannot be supported by statistical analysis, but, in line with the findings of other studies, the labial ceramic veneers performed excellently for each of the examined parameters during the short observation period. The original three-step adhesive rehabilitation technique restores the posterior region with overlays at an increased VDO; however our treatment combined the sandwich approach with the Dahl concept and used palatal veneers as anterior deprogrammers, to be followed by compensatory eruption for the relatively unaffected posterior teeth, reconstructing functional occlusion. This combination of adhesive techniques with the Dahl principle was introduced by Magne and others.[22] The Dahl concept allows maximal tooth structure preservation, without the need for posterior overlay restorations, with special attention to healthy molars and premolars. Poyser and others considered the clinically relevant studies related to the Dahl concept and found that the majority of the available literature originated from the United Kingdom.[24] Although case-reports are available, there is lack of international uptake of this technique.[22,24] On the other hand, the quality of the evidence from these studies is medium to low; thus, randomized controlled clinical trials are necessary to provide evidence-based data.[24] The original Dahl appliance is a removable, localized palatal bite-raising metal device which can create the necessary space for further full-coverage restorations of damaged anterior teeth.[25]

To overcome the problems associated with excessive tooth preparation for full coverage crowns, an adhesive double-veneer (palatal metal and labial ceramic) approach was introduced by Bishop and others.[39] The improvement and continuous development of adhesive dental materials ensure durable, ultraconservative solutions. The treatment of anterior tooth wear with direct RBC restoration placed in supra-occlusion at an increased VDO was described first by Darbar and Hemmings.[40] Direct RBC replaces the eroded tooth structure with an additive approach and additionally can be used as an anterior deprogrammer to reposition the mandible in centric relation.[8,22] Hemmings and others reported an 89.4% success rate of direct resin composite palatal veneers in the treatment of localized anterior tooth wear after 30 month follow-up, and the posterior occlusion was satisfactorily restored after a mean duration of 4.6 months with good patient satisfaction.[26] Redman and others, in their short-to-medium term study, confirmed that RBC restorations placed at an increased VDO are viable first-line options to treat anterior tooth wear; the authors concluded, however, that the probability of failure is increased after five years.[27] In their medium-term survival study, Gulamali and others concluded that more than 90% of the investigated direct and indirect RBC restorations had exhibited minor or major failure over the preceding ten years and required intervention and maintenance.[28] Mechanical limitations of RBCs can lead to marginal fracture and staining, but failures such as bulk fracture, surface roughness and discoloration are uncommon.[27] With respect to most deteriorations, a similar tendency was also detected in our study. However, survival of palatal restorations was found to be 100%. A few restorations had minor defects such as surface roughness, marginal discoloration, marginal adaptation, and consequent gingival inflammation after the short observation time. In line with Redman and others, surface roughness in one patient took the form of pitting, suspected to be due to the exposure of tiny voids as the palatal RBC wore and erosive effects softened the external layer.[27] In our cases, a nano-hybrid RBC was applied directly to the silicon matrix and pressed to the palatal surface of the tooth. Probably the absence of an intensive condensation phase is the reason for the voids and subsequent surface roughness. In contrast, a clinical study found that the indirectly made palatal veneer had a surprisingly higher incidence of roughness.[27] Despite the short observation period, marked small wear facets appeared frequently (USPHS "Bravo" score of 44.4%) on the palatal veneers, especially on

the static occlusal contacts. All six patients had suffered from night or awake grinding before the initiation of treatment; however, only two patients reported continuing bruxism after the palatal build-up. They received night-guard splints to prevent fracture of the veneers. Based on the detected wear facets, it is assumed that some degree of occlusal stress was still present in all patients, but the newly constructed anatomic palatal shape and designed guidance limited parafuntional movements, which were consequently less noticeable to the patients. Although only two of our participants needed night-guard splinting, it is important to emphasize that regular check-ups and maintenance are suggested for timely detection of signs of increased bruxism activity. As an alternative solution to decrease the risk of restoration failure, routine fabrication of a night-guard splint at the end of the restorative treatment could be beneficial. It is considered advantageous to use RBC restorations opposite worn teeth, since RBCs have lower wear resistance than the opposing teeth, and thus the wear rate of the antagonist could be decreased.[41,42] Further advantages of RBC for Dahl restorations are the maintainability, time- and cost-saving potential, and preservation of healthy tooth structures.[43] Moreover, it can protect exposed dentin from further wear, and the reversible nature of the approach may allow repair and an alternative restoration in the future. This technique offers good patient compliance and satisfaction, even when repair is needed. Our patients tolerated the increased VDO and posterior disclusion very well. They were maximally adapted within a short time, as has been reported in other studies as well.[26,27]

The palatal RBC restorations provided a deliberate occlusal plane and axial loading of the antagonist teeth; therefore no adverse tooth movements were detected on the anterior teeth. The fundamental importance of the reconstructed canine guidance lies in preventing fracture of the labial veneer by separating the upper and lower incisors during lateral movements. Already in the design or mock-up phase, it is necessary to determine the future length of the incisors and align them with the available interincisal space provided by the planned canine guidance. Furthermore, it is assumed that the stable anterior occlusion and guidance facilitate posterior tooth eruption by neuromuscular regulation. Posteruptive tooth movement maintains the position in occlusion by compensation for occlusal tooth wear. Although the actual mechanism of compensatory eruption is unclear, it is supposed that coordinated forces of the orofacial muscles, under the influence of the central nervous system, are responsible for tooth eruption.[44] Lund has described that the control of mastication depends on sensory feedback that serves to regulate muscle activity through all stages of mastication.[45] The individual chewing cycle is divided into three stages: opening, fast-closing, and slow-closing. The last is associated with the increased force required for grinding the bolus. It is speculated that when the posterior region is discluded, as in the case of only anterior contacts and guidance, the slow-closing phase and resultant increased elevator muscle activity are absent; thus the food mastication function is disrupted. The central nervous system receives several kinds of feedback from muscles, periodontal receptors, and touch receptors of the mucosa, and consequently induces bone remodeling and tooth eruption to maintain the physiologic function of the masticatory system. In our study, all subjects had re-established posterior contacts within four weeks. Redman and others found that of 31 patients, 61% had complete and 39% had partial re-establishment of posterior occlusion within two to 18 months, with a mean of seven months.[27] It is likely that mandibular repositioning and the youth of our patients contributed to the rapid results observed.

CONCLUSIONS

Within the limitations of this observational case-series, the present authors conclude that adhesively bonded labial ceramic and palatal direct RBC veneer—ie, sandwich veneer—in combination with the Dahl concept is a promising method for treating localized anterior tooth wear. The minimally invasive additive approach and the compensatory eruption of posterior teeth reconstruct esthetics and function with maximal preservation of the remaining tooth structure. Although, mechanical limitations of the direct RBC can lead to wear, marginal breakdown, marginal discoloration, and surface roughness, the maintenance of these palatal restorations is straightforward, with refinishing or with localized repair. There is a high degree of patient satisfaction associated with sandwich restorations. The temporary posterior disclusion is well-tolerated and contacts are re-established within a very short period of time.

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Regulatory Statement

The study protocol was approved by the Regional Research Ethics Committee of the University of Pécs (3410.1/PTE).

Conflict of Interest

The authors have no financial interest in any of the companies or products mentioned in this article.

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