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Digital Smile Design for Computer-assisted Esthetic Rehabilitation: Two-year Follow-up

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Clinical Relevance

The use of digital smile design is a useful resource for diagnosis, simulation, and evaluation of esthetic rehabilitation and it can improve communication among the patient, clinician, and dental laboratories.

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SUMMARY

Objective: The esthetics of the smile are related to the color, shape, texture, dental alignment, gingival contour, and the relationship of these with the face.

Purpose: To present a two-year follow-up for an esthetic rehabilitation clinical case in which the method of digital smile design (DSD) was used to assist and improve diagnosis, communication, and predictability of treatment through an esthetic analysis of the assembly: face, smile, periodontal tissue, and teeth.

Clinical Procedure: The smile's esthetics were improved through gingival recontouring, dental home bleaching, and a restorative procedure with thin porcelain laminate veneers using lithium disilicate glass-ceramic (e.max Ceram, Ivoclar-Vivadent) laminates on teeth 4 through 13.

Discussion: The proposed technique had an acceptable clinical performance at the end of a two-year follow-up.

Significance: DSD can be used to increase professional/patient communication and to

provide greater predictability for the smile's esthetic rehabilitation.

PURPOSE

The esthetics of the smile are related to color, shape, texture, dental alignment, gingival contour, and the relationship of these with the face.[1-3] To plan an esthetic rehabilitation, all of these parameters must be considered, and ideally, at the end of treatment, the expectations of patients should be achieved.

Planning through digital smile design (DSD)[4] allows an esthetic analysis of the assembly—face, smile, periodontal tissue, and teeth—through the analysis of extra- and intraoral digital photographs, in which the reference lines of the face and of the anatomical axes are plotted as a guide to establish a proper gingival contour, shape, and dental alignment. This provides greater predictability of treatment because it allows a final dental outline showing the relationship between the preoperative situation and the ideal design, in addition to assisting as a guide to diagnostic wax-up and consequently to the mock-up.[4]

A strategy used to assist in planning and predictability of treatment is making a dental cast following the completion of the mock-up,[5] in which the diagnostic wax-up is performed based only on the esthetic analysis of the teeth shapes and gingival contour. Despite the fact that facial analysis is not considered with this technique, this is the planning strategy performed in most of the cases reported in the literature.[6-9] Although it is a simple technique that does not require specific equipment or software for its achievement,[4] no case reports on the use of DSD were found.

Adequate planning may ensure a conservative, effective, and durable treatment. Sometimes dental bleaching may be a conservative alternative able to produce a good result;[10] however, when looking for a solution to esthetic problems, involving morphologic modifications in relation to tooth color, shape, contour, size, volume, and positioning, a restoring treatment is necessary.[11] Porcelain laminate restoration has proven to be a durable and esthetic modality of treatment.[12-16] The porcelain material commonly indicated for use in veneers is hot-pressed glass-ceramic because of its translucency and potential for use in small thicknesses.[17] This allows for a conservative tooth preparation because, by way of an adhesive cementation technique, the veneers are bonded to the enamel through resin luting systems, allowing such fragments to resist fracture.[18]

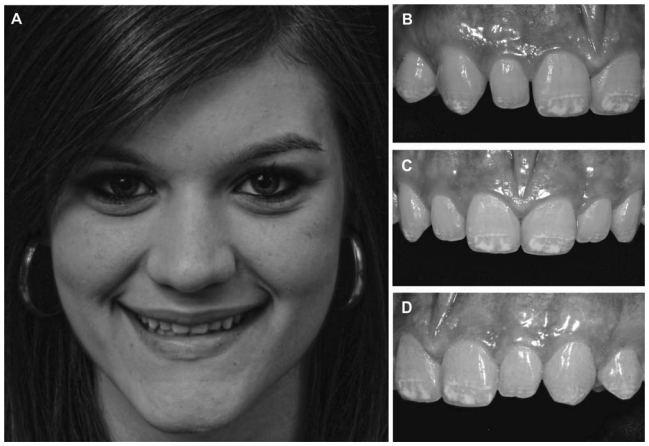

Figure 1. *Pretreatment aspect of the patient. (A) Facial view. (B-D) Intraoral view of the maxillary teeth. All anterior maxillary teeth exhibit enamel hypoplasia, a relatively dark color, and a disharmony of shape and proportion. The gingival margin of the left central incisor is more coronal than that of the right central incisor.*

All planning techniques and case studies are important and contribute to better outcomes in terms of the final rehabilitation treatment. However, the patient does not always have the ability to imagine the condition presented with the aid of plaster models and waxing implemented in an actual clinical situation. The DSD allows the patient to gain a prediction of treatment, facilitating understanding and allowing his critical analysis and participation in planning. Thus, the purpose of this article is to present a two-year follow-up for an esthetic rehabilitation clinical case in which the method of DSD was used to assist in the diagnosis, communication, and predictability of treatment through an esthetic analysis of the assembly: face, smile, periodontal tissue, and teeth. The DSD method may also help to improve the interaction between professional and patients, allowing their critical analysis in the treatment planning.

DESCRIPTION OF TECHNIQUE

A female patient, 19 years of age, was disappointed with her smile because of the appearance of what she called her "childlike smile" and the presence of white spots. The patient further pointed out that she would like her teeth to be whiter. After anamnesis and clinical examination, the presence of white spots on the facial surface of the upper teeth was observed. It was diagnosed as enamel hypoplasia, and there was also a disharmony of shape and proportion of the maxillary anterior teeth and the gingival contour. The pretreatment aspect—facial and intraoral views of the patient—is shown in Figure 1.

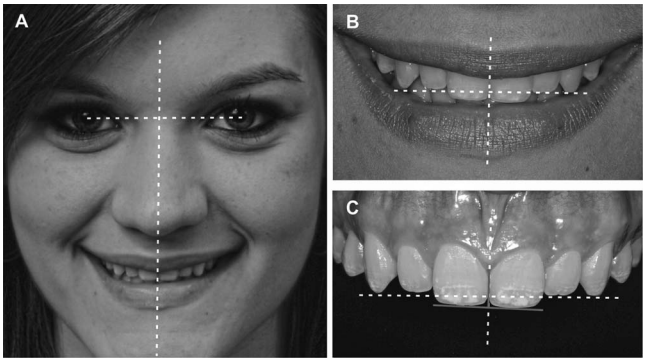

Figure 2. *Digital smile design (DSD) protocol. (A) Determining the ideal horizontal plane and vertical midline on the facial photograph. (B) Transferring the cross to the intraoral photography to establish the vertical midline and occlusal plane. (C) Drawing the three reference lines that allow for the analysis of the relationship among the facial lines, lips, teeth, and gingiva.*

Digital Planning

To obtain better predictability of the proposed treatment and to facilitate communication among the interdisciplinary dental team, in addition to the manufacture of the dental cast and conducting extra and intraoral photographs, the digital planning of the case was accomplished with the help of a presentation software, Keynote (iWork, Apple, Cupertino, CA, USA), by the DSD technique, as described previously.[4]

First, the three photographs required for DSD analysis were performed, as follows: full face with a wide smile, full face at rest, and retracted view of the full maxillary arch with teeth apart. In the photograph of the full-face smile, the horizontal plane and the median sagittal plane were determined according to the interpupillary line and anatomical references such as the glabella, nose, and chin, respectively (Figure 2A). These two lines were transferred to the intraoral photography (Figure 2B) to analyze the smile in accordance with the facial references. The dental midline and occlusal plane were established (red line—Figure 2C), and their relationship with the facial lines (dashed yellow line) was analyzed.

After the facial analysis the dental analysis was performed. A rectangle with the actual proportion of maxillary teeth and tooth outline were accomplished to analyze the shapes and width/length proportions of the pretreatment teeth (Figure 3A). Then a rectangle with the ideal length/width proportion was placed over the teeth to compare the actual pretreatment proportions with the ideal ones (Figure 3B). Furthermore, measurements in the digital photographs were performed and transferred to the dental cast to calibrate the digital ruler and guide

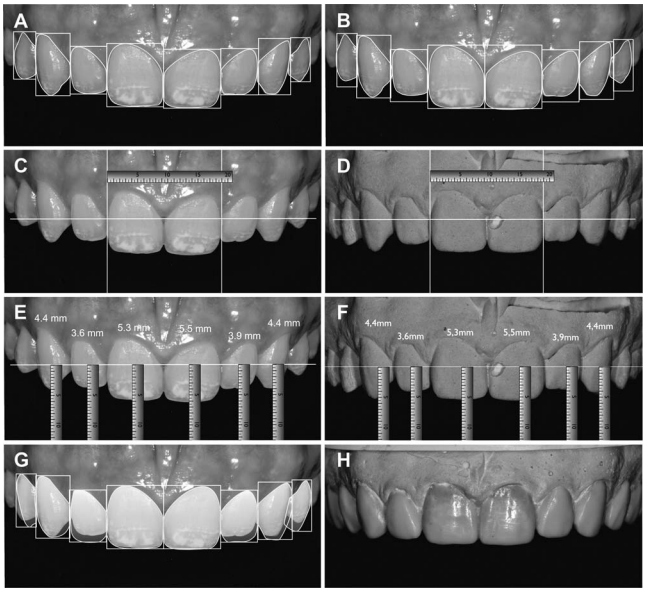

Figure 3. *Digital smile design (DSD) protocol. (A) A rectangle is placed over the maxillary teeth, and outlines of the teeth were accomplished to define the shapes and proportions of the pretreatment teeth. (B) A rectangle with the ideal length/width proportion is placed over the teeth to compare the actual pretreatment proportion with the ideal one. (C,D) Measurement of the width of the central incisors on the photograph and cast for calibration of the digital ruler. (E) Measurement of the distance between the horizontal line and incisal edge on the photograph. (F) This measurement is transferred to the cast. (G) Final teeth outline and gingival contour showing the relationship between the preoperative situation and the final design. (H) The diagnostic wax-up is fabricated using the DSD as a guide.*

the diagnostic wax-up (Figure 3C-F). The final teeth outline and gingival contour were planned (Figure 3G), and the diagnostic wax-up was fabricated using the DSD as a guide (Figure 3H).

Treatment Plan

After planning the case and discussing the treatment options with the interdisciplinary dental team, the DSD was used as a tool for communicating with the patient to clearly illustrate the treatment and discuss whether or not it met the patient's expectations. After obtaining patient consent, the treatment plan was defined; this plan integrated the performance of gingivoplasty in tooth 9, dental bleaching, and a restorative procedure with thin ceramic laminate veneers on teeth 4 through 13 in order to improve the esthetics of the smile with minimal reduction of healthy tooth structure.

Gingivoplasty

Initially, gingivoplasty was performed on tooth 9 to raise the gingival margin in the apical direction and to realign the gingival zenith to match the equivalent teeth. After anesthetizing the region, an

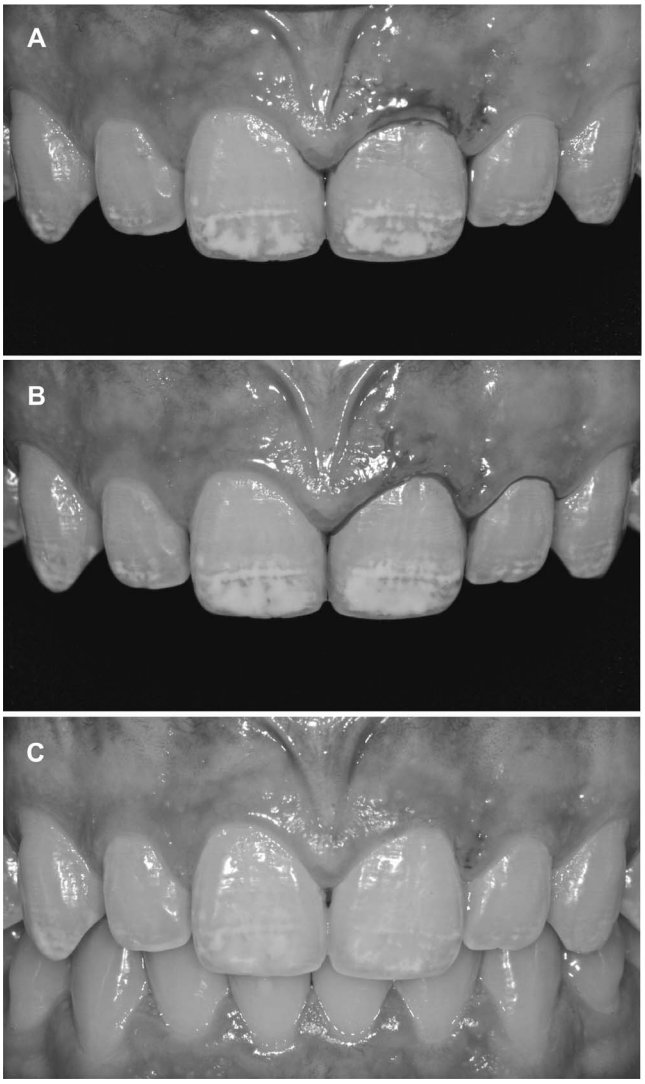

Figure 4. *Gingivoplasty of the left central incisor. (A) The left central incisor after the incision from the margin of the free gingiva. (B) Final aspect of gingivoplasty at the left central incisor. Note the rise in the gingival margin to the apical direction and the realignment of the gingival zenith like the contralateral tooth. (C) Clinical aspect after 24 hours of follow-up. Note the satisfactory aspect of the alignment of the gingival margin and tissue healing.*

internal bevel incision from the margin of the free gingiva was made with scalpel blade 15C, and gingival tissue was removed with a McCall 13-14 curette (Figure 4A,B). One week postoperatively it was possible to observe a satisfactory aspect of the alignment of the gingival margin and tissue healing (Figure 4C).

Dental Bleaching

After healing of the periodontal tissue, dental home bleaching was performed on the upper and lower teeth using 16% carbamide peroxide gel (Whiteness, FGM Produtos, Joinville, SC, Brazil) one hour and 30

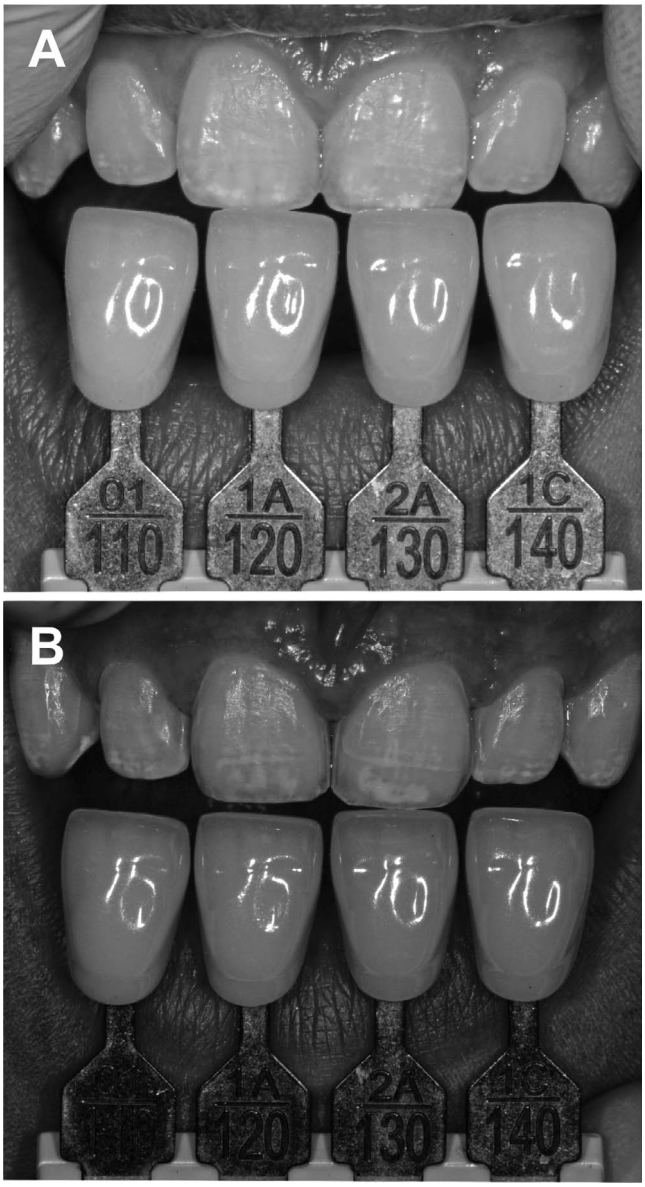

Figure 5. *Dental bleaching. (A) Aspect of the teeth before dental bleaching. (B) Final aspect of the teeth after 21 days of dental bleaching with 16% carbamide peroxide gel.*

minutes per day for 21 days.[19] Figure 5 shows the appearance of the teeth before and after the completion of the dental bleaching, demonstrating that the color registration obtained by the color scale (Vita-Pan 3D master, Vita, Bad Säckingen, Germany) was originally A2 (Figure 5A) and passed to B1 at the end of the dental bleaching process (Figure 5B).

Restorative Procedure with Thin Ceramic Laminate Veneers

Meanwhile, a dental cast of the patient was obtained for preparation of the wax-up and for the construc-

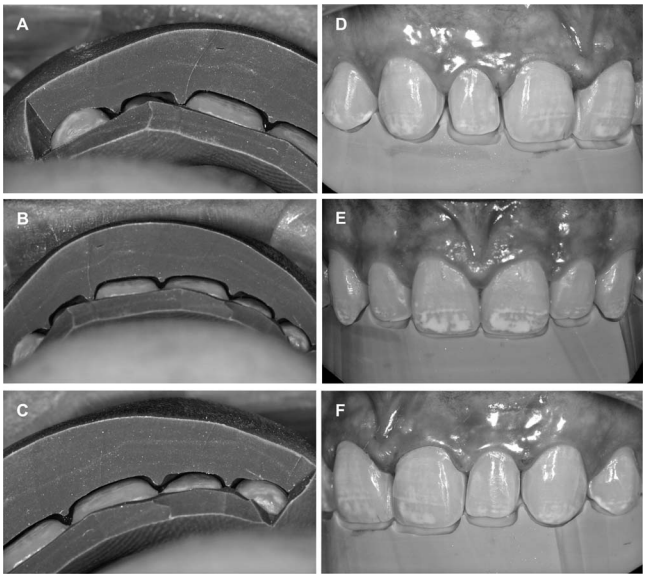

Figure 6. *The silicone matrix used to guide and check the amount of reduction in tooth preparation to the restorative procedure with thin ceramic laminate veneer. (A-C) Occlusal view of the silicone matrix used to guide the tooth preparation on the facial surface. (D-F) Frontal view of the silicone matrix used to guide the tooth preparation on the incisal third.*

tion of the mock-up. This procedure allows a tridimensional intraoral revisualization of the final result prior to tooth preparation, allowing for anatomical changes and adjustments.[20] From the dental cast with wax-up, two silicone (Express XT, 3M ESPE, St Paul, MN, USA) impressions were obtained. One was for guidance and verification of the need for reduction, thus creating a reference for the horizontal and vertical extent of the preparation (Figure 6), and the other was used for the mock-up and the provisional restorations.

Twenty-one days after the completion of dental bleaching, teeth 4-13 were prepared for thin ceramic laminate veneers. The tooth reduction, restricted to a small thickness of the enamel, was performed with diamond tip 2135 (KG Sorensen, São Paulo, SP, Brazil) on the facial surface of the tooth. For the proximal area, metal sandpaper (KG Sorensen) was used to create a separation between the teeth in order to facilitate the definition of the proximal margin, the impression procedure, and the positioning of the veneers. The cervical end was beveled to the subgingival level. The incisal third was prepared, reducing only the buccal surface, maintaining enamel tissue in this region. During this phase, it was important to use the silicone matrix, obtained from the wax-up, to guide the amount of reduction in tooth preparation (Figure 6). To refine the tooth preparation margin, diamond tips F (fine), FF

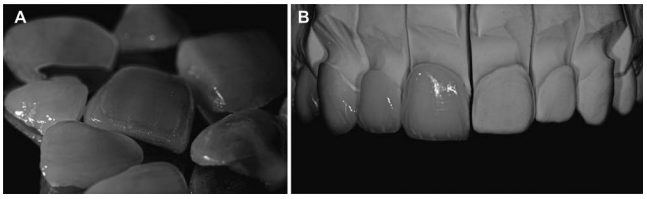

Figure 7. *The thin ceramic laminate veneer. (A) The translucence of the thin ceramic fragments. (B) Positioning the thin ceramic laminate veneer on dental cast to verify marginal adaptation, alignment, shape, and color. Note the difference between the thin ceramic laminate veneer positioned on the dental cast on the right and the thin ceramic laminate veneers not positioned on the dental cast on the left.*

(extrafine) 4138 (KG Sorensen), and abrasive disks (Sof-Lex Pop-on, 3M ESPE) were used to leave all rounded angles. The final amount of reduction was 0.5 mm in the middle third and 0.2 mm in the cervical third.

For the impression of prepared teeth, placement of two cords (UltraPack, Ultradent, São Paulo, SP, Brazil) was used for gingival retraction, with the impression technique a double mixture in two steps with vinyl polysiloxane in heavy and light consistencies (Express XT, 3M ESPE). Then color selection was performed for the ceramic laminate veneers with the help of a color scale (Vita-Pan 3D master, Vita) and the provisional restorations made with a Bis-acryl resin (Protemp, 3M ESPE). The maxillary and mandibular casts were sent to the dental technician for manufacturing of the ceramic laminates (e.max Ceram, Ivoclar-Vivadent, Schaan, Liechtenstein).

Prior to cementing, the ceramic laminates were carefully positioned to verify marginal adaptation, alignment, shape, and color (Figure 7), with satisfactory results. A shade match with the color of the selected cement was established through the try-in pastes, and the translucent cement was selected. For luting, the conditioning of the internal surfaces of the restorations was performed through application of 10% hydrofluoric acid (Porcelain Conditioner, Angelus, Londrina, PR, Brazil) for 20 seconds, washing with water and air-drying, then conditioning with 37% phosphoric acid (Acid Gel, Villevie, Joinville, SC, Brazil) for one minute, washing with water, and air-drying; afterward, a silane (Dentsply, York, PA, USA) and adhesive (Adper Scotchbond Multi-purpose, 3M ESPE) were applied. After isolation of the soft tissues, teeth were conditioned with 37% phosphoric acid (Acid Gel, Villevie) for 30 seconds, and then rinsing and drying were performed. Afterward, the adhesive (Adper Scotchbond Multi-purpose, 3M ESPE) was applied. Resin cement (Variolink Veneer, Ivoclar-Vivadent) was used as a

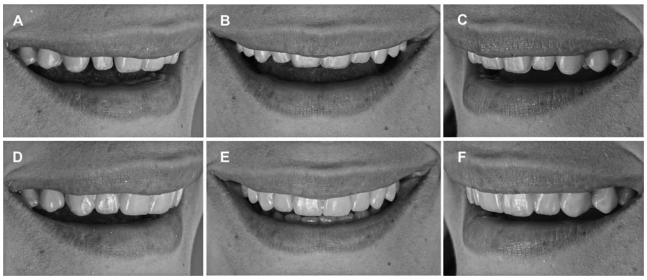

Figure 8. *The patient's smile before (A-C) and after (D-F) treatment.*

luting agent. It was applied to the internal surface of the ceramic laminate which was then positioned and light-cured (Radii Cal, SDI, Bayswater, Australia) on the facial and lingual sides for 40 seconds. The luting of the ceramic laminates was performed following the same sequence for each tooth. After luting of all veneers, the cervical margins were verified, and the excess cement was removed. The finishing and polishing of the cement line were performed with abrasive discs (Sof-Lex Pop-on, 3M ESPE).

Immediate Result and Clinical Follow-up

The intraoral aspects of the patient can be seen before (Figure 8A-C) and after (Figure 8D-F) treatment completion. The facial view after treatment can be seen in Figure 9. The clinical follow-up with the intraoral aspects of the patient can be seen after six months (Figure 10) and after two years (Figure 11) of treatment.

Esthetic match, porcelain surface, marginal discoloration, and integrity were carefully examined for restoration following modified California Dental Association/Ryge criteria[21,22] at the recalls performed at the end of six months and two years. The ceramic laminate veneer after six-month and two-year follow-ups was rated as acceptable (Alpha scores were observed for all evaluation criteria).

POTENTIAL PROBLEMS

Esthetic rehabilitation planning must be performed through thorough evaluation that includes a facial analysis, dental-facial analysis, and dental analysis.[1-3] The dental literature recommends gathering the diagnostic data through forms and checklists;[23] however, nothing indicates how the information ideally should be gathered and implemented. Therefore, many of these diagnostic data may be lost if they are not transferred in an adequate way to the rehabilitation design. The DSD protocol[4] performed in this case allows a thorough analysis of the esthetic principles through the drawing of reference lines on

Figure 9. *The patient's facial view after treatment.*

Figure 10. *The patient's smile after six months of clinical follow-up.*

Figure 11. *The patient's smile after two years of clinical follow-up.*

digital photographs that in a predetermined sequence are transferred to a cast model and serve as a guide for diagnostic wax-ups, thereby preventing loss of diagnostic data.[4,24,25] Although the DSD is a simple technique that does not require specific equipment or software for its achievement, training and handling are required, but because of the simplicity of the technique may not represent a limitation.

In the present case, veneers were made with lithium disilicate glass-ceramic. These ceramics provide excellent esthetic value and demonstrate high translucency, just like natural dentition.[8] However, the final shade of the veneers depends not only on the shade, opacity, and thickness of the porcelain but also on the shade of the underlying tooth and the shade and thickness of the luting composite.[26,27] Therefore, in this case the color of the resin cement was established through the try-in pastes. These pastes simulate the shade effect of ceramic restorations, allowing the choice of an ideal shade of the luting resin that does not compromise the final shade of the veneers. Another limitation of the minimally invasive ceramic veneers is the inability to mask severely stained teeth.[28] However, ceramic veneers had a satisfactory cosmetic result in this case, in which teeth were affected by enamel hypoplasia.

Ceramic laminate can be considered a conservative treatment option for reestablishing aesthetic teeth[9] because it enables minimally invasive veneer preparation designs. These involve less tooth reduction and minimal porcelain thickness.[11] The thin laminate can cause an increased risk of crack formation and fracture in luting due to the stress

generated by polymerization shrinkage.[29] As a result of their high mechanical properties, glass-ceramics, with flexural strength of approximately 306 MPa,[30] can be used in clinical situations when higher flexure risk factors are involved,[31] as in minimally invasive ceramic veneers. With this material, it is possible to have thicknesses of less than 0.5 mm with or without preparation of the enamel because of their increased strength and fracture toughness, as well as the presence of sufficient room to achieve the desired esthetics.[31] However, since the thin laminate veneer is a new treatment modality, longitudinal clinical studies are necessary to understand whether the small thickness of the ceramic veneers does not compromise their mechanical strength and long-term clinical behavior.

The preparation technique for porcelain laminate veneers is important for the longevity of the restoration because the high failure rates of these restorations have been attributed to the large exposed dentin surfaces.[18] Although improved new adhesives and resin luting cement have been developed, the bond strength of porcelain to enamel is still superior compared with the bond strength of porcelain to dentin.[32] Dentin substrate has a lower inorganic content, tubular structure, and variations in this structure, along with the presence of outward intratubular fluid movement, may result in the aging of the restoration through hydrolytic degeneration of the interface components, resin, and/or collagen. This can be considered one of the main reasons for resin degradation within the hybrid layer, which contributes to the reduction in bond strengths between dentin/adhesives over time.[33] Therefore, the preparation should be done completely in enamel to maintain an optimal bond with the porcelain laminate veneers[32] and to obtain a greater clinical longevity for this restoration,[18] as was the case in this clinical case.

SUMMARY OF ADVANTAGES AND DISADVANTAGES

The DSD protocol allows for esthetic planning through the drawing of reference lines and the final dental design on extra- and intraoral digital photographs. That protocol widens the diagnostic vision and helps the team members measure the treatment limitations and risk factors such as asymmetries, disharmonies, and violations of esthetic principles. In addition, the DSD protocol provides a greater predictability of treatment and facilitates the communication between the interdisciplinary team members and the dental technician. Because the protocol allows for the viewing of the relationship between the preoperative situation and the ideal design, it serves as a guide to conduct the diagnostic wax-up more efficiently by focusing on developing anatomical features within the parameters provided, such as planes of reference, facial and dental midlines, recommended incisal edge position, lip dynamics, basic tooth arrangement, and the incisal plane. The protocol is also an amazing tool for communicating with patients, because the clinician is able to clearly illustrate the issues and possible solution, thus balancing the patients' expectations as well as increasing their understanding of the treatment plan and discussions of the prognosis. In addition, with the drawings and reference lines, it is possible to perform comparisons between the before and after pictures, which allows for a precise reevaluation of the results obtained in every phase of treatment.[4,34-36] On the other hand, this protocol requires a lot of time and has a relatively high cost, which makes this approach less accessible to all patients.

In this case report, the patient complained about the esthetics of her smile, which presented enamel hypoplasia on the facial surface of the upper teeth, and a disharmony of shape and proportion of the maxillary anterior teeth and the gingival contour. Treatment possibilities using gingivoplasty, dental bleaching, and laminate veneers, as well as their advantages and limitations, were shared with the patient.

With the intention of improving the final esthetic result, gingivoplasty on tooth 9 and a bleaching protocol were established as the first steps of the treatment. During the gingivoplasty, an internal bevel incision was made from the free gingival margin to prevent the exposure of connective tissue and to provide for a comfortable postoperative experience and rapid healing. The dental bleaching in less severe cases of enamel hypoplasia may be a conservative alternative able to generate good results, but it can also increase the risk of highlighting the spots.[10] Nevertheless, the desire to modify the shape, size, volume, and tooth position was key to the choice of the restorative treatment. The dental bleaching was necessary because the final color exhibited by a porcelain veneer will be the result of the interaction among the porcelain laminate, substrate, and luting cement.[26,37]

Although composite resin can be used to mask tooth discolorations and to correct unaesthetic tooth shape and position, this type of restoration still suffers from limited longevity because the material

remains susceptible to discoloration, wear, and marginal fractures, thereby reducing the esthetic result in the long term. On the other hand, porcelain veneers have proven to be durable anterior restorations with superior esthetics.[12,13,38] This type of restoration presents lower failure rates with regard to long-term survival and is considered more durable than direct composite veneers as long as the patients are adequately selected, the veneers are prepared following meticulous clinical procedures, and the available materials and techniques are correctly applied.[12,30]

With the intention of performing the minimally invasive veneer preparation designs, the silicone matrix obtained from the wax-up was used as a guide during the tooth preparation.[6] One critical step in the porcelain laminate technique is the achievement of sufficient ceramic thickness, and the guide allows for more enamel preservation and, as a consequence, more predictable bonding, biomechanics, and esthetics. Another strategy used to improve the predictability of the treatment was the mock-up, which allows for a tridimensional intraoral revisualization of the final result. This not only allows us to make adjustments and anatomical changes to obtain the best esthetic, phonetic, and functional outcomes but it also allows for better communication with the patient and laboratory.[20]

The porcelain laminate veneer technique includes the bonding of a thin porcelain laminate to the tooth's surface with adhesive techniques and resin cement.[12] For the longevity of this treatment, the strength and durability of the adhesion formed between the veneers and the tooth complex are crucial.[39] In the present report, the clinician used 'gold standard' materials such as a three-step etch-and-rinse adhesive system and light-cured luting resins. This is a photocured material that has a greater clinical longevity, greater bonding strength to the enamel substrate,[14,18,32] and stability of cement color over time.[40] It is known that the light transmission through veneers affects the degree of polymerization of light-polymerized resin luting agents, and the intensity of light transmitted through ceramic veneers was dictated by the polymerization unit and the type and thickness of the ceramic.[41] The IPS Empress e.max Press ceramic veneer is a translucent material and was used with a small thickness that does not compromise the polymerization process of resin cement,[42] resulting in a greater degree of conversion that will lead to more stable color after polymerization[40] and better esthetic results.

In the present report, the esthetic rehabilitation planning was adequately performed, the patient and technique were adequately selected, and materials were correctly applied, resulting in satisfactory esthetics immediately and after two years of follow-up.

CONCLUSION

This clinical report described the DSD protocol for esthetic rehabilitation. The DSD is a tool that assists with the diagnostics and allows the clinician to better predict treatment outcomes by using analysis of the esthetic principles in extra- and intraoral digital photographs. In addition, implementation of a digital dentistry tool can improve communication among the patient, clinician, and dental laboratories and may become a common technique for all esthetic rehabilitations. The DSD is a simple technique that does not require specific equipment or software; however, training and handling are required.

The treatment using gingivoplasty, tooth whitening, and thin ceramic laminate veneers, when done using appropriate materials and techniques, is a minimally invasive approach and is a feasible option for esthetic rehabilitation, showing satisfactory clinical applicability and contributing to the aesthetic result over two-year follow-up.

Acknowledgment

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Federal University of Pelotas in Brazil.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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