

## Article

# A Quality Study on Patients' Perceptions After Digitally Driven Smile Creation Including Aligners and Minimally Invasive Prosthetic Restorations

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## Abstract

**Background:** Aesthetic dentistry increasingly demands minimally invasive, predictable, and patient-centered solutions. Digital technologies and AI-driven planning tools are now integral to interdisciplinary treatments. **Aim:** To evaluate, by means of a 16-item questionnaire, patients' perceptions of smile aesthetics and oral function before and after receiving clear aligner therapy followed by minimally invasive ceramic veneers, using digital planning and Smile Creator software. **Materials and Methods:** Five adult patients underwent digital smile design, clear aligner therapy, and feldspathic veneer placement. Pre- and post-treatment perceptions of smile aesthetics and function were assessed using a structured questionnaire. AI-based simulation tools (2D and 4 K TruSmile video previews) were incorporated. Paired *t*-tests were used to compare outcomes before and after treatment. **Results:** Mean pre-treatment scores were 4.8 for smile aesthetics and 6.6 for function. Post-treatment scores significantly improved to 9.8 ( $p = 0.001$ ) and 9.4 ( $p = 0.002$ ), respectively. Patients rated AI-generated smile previews more favorably than 2D designs and acknowledged the value of digital tools in understanding and accepting treatment. **Conclusions:** The integration of digital and AI-based tools in aesthetic dentistry enhances patient communication, improves predictability, and enables minimally invasive treatment. Patient satisfaction was high, underscoring the effectiveness of the combined orthodontic and prosthetic approach.

**Keywords:** aesthetics; feldspathic veneers; smile creator; digital smile design; aligners; mock-up; minimal invasive restoration; AI simulation



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## 1. Introduction

A perfect smile is typically defined as a harmonious and balanced aesthetic outcome resulting from the ideal alignment, proportion, symmetry, and color of the teeth in relation to the lips, gingiva, and overall facial features. It extends beyond mere dental alignment—it encompasses a balance of aesthetic harmony, emotional expression, and functional stability. In contemporary society, an attractive smile is often perceived as a symbol of health, confidence, and social appeal. According to Kokich et al., "Aesthetic dental treatment should

aim to create a smile that is harmonious in terms of tooth proportions, color, alignment, gingival architecture, and its integration with the patient's facial features" [1]. As a result, dental aesthetics has become a major focus of both patient expectations and clinical practice. The modern demand for smile enhancement has shifted from purely functional restorations toward treatments that incorporate both beauty and subtlety, with patients increasingly seeking outcomes that appear naturally aesthetic rather than unnaturally white or artificial. Achieving a smile that is both visually appealing and natural remains a central challenge in restorative dentistry. The goal is to meet patients' aesthetic expectations while preserving dental tissues through minimally invasive procedures. In this context, ceramic laminate veneers—particularly those fabricated from feldspathic and glass-ceramic materials—are recognized for their excellent survival rates and minimal biological cost [2,3]. However, optimal aesthetic and functional outcomes depend heavily on the position and alignment of the anterior teeth, which influence both the visual proportions of the smile and the occlusal balance. Pre-prosthetic orthodontics plays a crucial role in establishing ideal spatial conditions and proper tooth inclination for restorations, especially in cases where a confirmative prosthetic approach is desired [4]. Recent advances in clear aligner therapy offer a patient-friendly orthodontic alternative that supports this paradigm of minimally invasive, prosthetically guided treatment. Aligner systems can be used to achieve precise tooth movements aligned with the final restorative outcome, often improving both functional parameters and patient acceptance [5]. These systems are particularly valuable when employed as part of an interdisciplinary approach that integrates orthodontic and prosthetic planning from the outset. Digital technologies have revolutionized treatment planning and execution in aesthetic dentistry. Tools such as "Digital Smile Design (DSD)" software allow clinicians to digitally plan and visualize the ideal smile by integrating facial and dental analyses, evaluating the spatial relationships between teeth, gingiva, lips, and face using calibrated facial and intra-oral imagery [6–8]. These tools enable dynamic communication among clinicians, technicians, and patients, enhancing diagnosis and treatment predictability, and also promoting shared understanding and facilitating acceptance of the proposed treatment plan. Digital workflows also permit the creation of precise mock-ups and wax-ups that serve both diagnostic and motivational purposes [9,10]. Despite the technical precision and aesthetic potential of such treatments, patient satisfaction is ultimately determined by individual perception. The subjective nature of beauty means that clinical success does not always translate to perceived satisfaction. Therefore, evaluating patient-reported outcomes is essential to understanding the effectiveness and acceptance of aesthetic treatments [11]. The present study aimed to quantitatively assess patients' perceptions of smile aesthetics and function before and after receiving an interdisciplinary treatment that combines digital planning, clear aligners, and minimally invasive ceramic veneers. By means of a structured questionnaire, this study seeks to provide insight into how patients experience aesthetic transformation and to what extent digital, orthodontic, and prosthetic integration meets their expectations.

## 2. Materials and Methods

Patients to be treated with aligners and feldspathic veneers, in a private clinic in Rome, Italy, as part of usual professional practice and with no adjunctive risks, were enrolled in this study and asked to fill out a questionnaire. The research question was to evaluate whether the patients' perceptions of aesthetic and function increase with the pre-visualization of the final smile using 2D and 3D software, in patients treated with aligner therapy and minimally invasive prosthetic restorations.

The data were evaluated at the Department of Medicine, Surgery, and Pharmacy, University of Sassari, Italy. The 2013 Helsinki Declaration and the Good Medical Practice

principles were adhered to. Medical data were anonymized so that patients could not be identified. All the patients signed an informed consent for the data acquisition and treatment execution. In addition, according to the European laws, patients also gave consent for photo and video recording, immediately before acquisition, for compliance with the General Data Protection Regulation (GDPR). Ethics committee approval was not requested due to the qualitative nature of the research.

### *2.1. Inclusion and Exclusion Criteria*

Inclusion criteria were as follows: patients in good health; aged at least 18 years; requiring a minimally invasive improvement of the aesthetic smile with ceramic veneers in the anterior maxilla; with healthy teeth; and available to be treated with aligners. Exclusion criteria were as follows: patient ASA 3 or 4; untreated periodontitis and/or poor oral hygiene and motivation; heavy smokers (more than 11 cigarettes/day); pregnancy or nursing; substance abusers; psychiatric problems or unrealistic expectations. At the first visit, digital impressions (Medit i700, Medit Corp., Seoul, Republic of Korea), radiographs (orthopantomography), and intra-oral and facial photos (Nikon 850, Nikon Corporation, Tokyo, Japan) were taken.

### *2.2. Standardized Protocol for Patient Photo Recording*

Standardized digital images were obtained for each patient, including a full-smile image and a retracted intra-oral image captured under consistent lighting and positioning. Buccal corridors were fully exposed using cheek retractors to ensure comprehensive visualization. Key anatomical reference points were manually placed on both the retracted and smiling images to facilitate accurate alignment within dedicated software (exocad Elefsina 3.2, Smile Creator, exocad GmbH, Darmstadt, Germany). Images were adjusted for scale and orientation as needed. A 3D facial scan could be imported to enhance spatial representation and ensure facial harmony in the design. The digital design process included outlining the lip line and other relevant facial reference lines. Aesthetic guidelines and curvature lines (e.g., incisal, gingival, midline) were superimposed to guide restorative planning. Virtual modeling of the anterior teeth was performed to achieve the desired shape, proportion, and size, with consideration for natural morphology. Tooth shade and translucency parameters were digitally adjusted to simulate realistic aesthetic outcomes. A 3D simulation of the proposed smile was generated to assess visual and functional harmony. A comprehensive smile report (exocad Elefsina 3.2, Smile Creator, exocad GmbH, Darmstadt, Germany) was created, documenting the proposed design along with before-and-after image comparisons. Digital wax-ups were generated to serve as diagnostic and communication tools for both clinical planning and patient education. The software's automated eye-detection feature was used to enhance facial orientation. Additional design curves and symmetry lines were incorporated to refine aesthetic precision. A detailed PDF report was exported to summarize the design process and outcomes. The digitally designed smile was presented to the patient using high-resolution visuals to facilitate understanding and feedback. The approved design served as the foundation for subsequent clinical steps, including mock-ups, provisional restorations, or definitive prosthetic interventions.

### *2.3. Standardized Protocol for Patient Video Recording*

A standardized protocol was followed to ensure consistent and high-quality patient video documentation using a mobile phone (exocad Elefsina 3.2, TruSmile, exocad GmbH). The mobile phone camera (iPhone 13 Pro Max, Apple, Cupertino, CA, USA) was set to 4 K (4096 p) resolution. The frame rate was set to 60 frames per second (FPS) for optimal balance between quality and file size, and the video was recorded in mov format. All recordings were made in portrait mode to ensure compatibility with final video formatting.

No digital or optical zoom was used. Instead, the camera was physically positioned to achieve proper framing. Video duration was limited to 30 s. Longer recordings were trimmed using video editing software. The mobile phone was mounted on a tripod to ensure a steady and shake-free recording. A white background was used, avoiding patterns and varying colors. Optimal lighting conditions were ensured by using a ring light placed in front of the patient, aligned with the camera. The camera was positioned directly in front of the patient at the level of the smile, aimed toward the center of the nose. The patient's head was placed in the upper part of the frame, with the teeth approximately in the center. The framing ensured that the head was neither too large nor too small within the image. A frontal, neutral camera angle was maintained, avoiding high, low, or oblique views. The patient was seated comfortably with hands resting on their lap. Head Position: the head was kept upright and directed straight toward the camera. The patient was instructed to speak naturally throughout the video, smile and laugh spontaneously, and clearly expose their teeth. The patient was also advised to avoid the following during the recording: rapid head or body movements, turning the head excessively such that both mouth corners were not visible, biting the lips or protruding the tongue, covering the mouth with the hands, and moving out of frame.

#### *2.4. Digital Mock-Up and Orthodontic Treatment*

The created design and video were shown and discussed with the patient to assess the aesthetic discrepancy between the current and ideal smile, and to evaluate the patient's expectations. Based on the restorative strategy, orthodontic treatment with clear aligners was selected to reduce the need for aggressive tooth preparation, optimizing minimally invasive veneer preparation. The orthodontic phase was digitally planned using ClinCheck<sup>®</sup> software (Align Technology, Inc., San Jose, CA, USA), allowing for detailed visualization of the treatment, assessment of occlusion, dental arch asymmetries, and functional analysis. Targeted dental movements were programmed to align the teeth and optimize their position for conservative veneer preparation. Attachments were incorporated as needed to improve movement precision. The patient was instructed to wear upper and lower aligners for 22 h per day, changing them weekly. The duration of aligner therapy ranged from six to twelve months, depending on initial conditions.

#### *2.5. Prosthetic Treatment*

Following orthodontic alignment, a digital wax-up of the ideal tooth morphology was created and tested using a mock-up (GC UNIFAST III, GC Europe, Leuven, Belgium). Guided no-prep or minimally invasive veneer preparations were then performed through the mock-up to preserve as much enamel as possible. A vertical finish line design was adopted to allow flexibility in the final cervical contours (6863D and 8863D, Komet Dental, 32657 Lemgo, Germany). Final impressions were taken using the double retraction cord technique (00 and 0 Ultrapack, Ultradent, Köln, Germany) and a Polyether Impression material (3M<sup>™</sup> Impregum<sup>™</sup>, 3M Italia Srl, Milan, Italy). Feldspathic veneers were fabricated and cemented using adhesive protocols. The enamel was conditioned via sandblasting with 50- $\mu$ m aluminum oxide, followed by 37% phosphoric acid etching. The veneers were also sandblasted (50  $\mu$ m, 0.2 MPa), treated with 9.5% buffered hydrofluoric acid, and cleaned with steam. A dedicated primer was applied (Clearfil Ceramic Primer, Kuraray Noritake, Hattersheim, Germany) and maintained for 30 s. Finally, the veneers were cemented using PANAVIA V5 Clear (Kuraray Noritake, Germany). Post-operative evaluations were scheduled at one week, one month, and six months to monitor integration of the restorations with soft tissues and to assess functional performance. A removable retainer was delivered after one week to ensure long-term stability. An explanatory case is reported in Figures 1–12.



**Figure 1.** Initial situation. Intra-oral frontal picture in occlusion.



**Figure 2.** Initial situation. Intra-oral frontal picture, maxillary teeth.



**Figure 3.** Initial situation. Extra-oral frontal picture with smile.



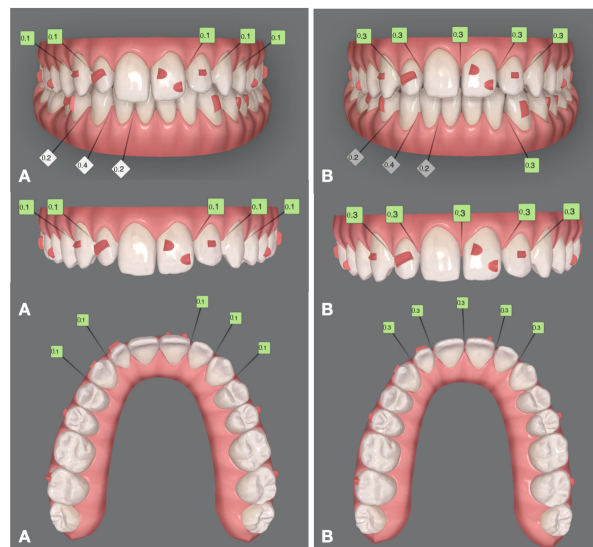
**Figure 4.** Initial situation. Extra-oral frontal picture with retractor.



**Figure 5.** Pre-visualization with Smile Creator (exocad Elefsina 3.2, Smile Creator, exocad GmbH).



**Figure 6.** Pre-visualization with TruSmile (exocad Elefsina 3.2, Smile Creator, exocad GmbH).



**Figure 7.** ClinCheck® (Align Technology, Inc., San Jose, CA, USA) with the comparison between the pre-treatment condition (A) and the final digital plan (B) with the recovery of ideal space distribution (green box) and tooth inclination in the maxillary arch.



**Figure 8.** Mock-up: preparation using acrylic resin and silicone mask.



**Figure 9.** Mock-up: smile view.



**Figure 10.** Minimally invasive preparations for feldspathic veneers.



**Figure 11.** Feldspathic veneers two weeks after adhesive cementation.



**Figure 12.** Extra-oral picture. Patient's smile.

### 2.6. Primary Outcome

Patient satisfaction was evaluated using a short form questionnaire (16 questions).

#### Patient Questionnaire: Evaluation of Digital Smile Design and Treatment Outcomes

1. What were your main reasons for seeking treatment? (Select all that apply):
  - Aesthetics (shape/volume)
  - Function
  - Tooth color
  - Alignment
2. On a scale from 0 to 10, how would you rate the aesthetics of your current smile?
3. On a scale from 0 to 10, how would you rate the functionality of your current smile (e.g., chewing, speaking)?
4. Would you be willing to undergo orthodontic treatment with aligners to improve aesthetics and/or function?
  - Yes
  - No
5. Regarding tooth shape and appearance, which do you prefer?
  - A natural, harmonious smile
  - An idealized, "perfect" or flawless smile
6. Do you prefer:
  - A natural tooth color
  - A bright "super white" shade
7. On a scale from 0 to 10, how would you rate the 2D digital aesthetic preview of your smile?
8. On a scale from 0 to 10, how would you rate the 3D digital aesthetic preview of your smile?
9. Based on the previews, how satisfied are you with the proposed aesthetic outcome so far?
  - Very satisfied
  - Fairly satisfied
  - Slightly satisfied

- Not at all satisfied
10. After reviewing the mock-up, how well did the tooth shape meet your expectations? (0 = not at all, 10 = perfectly)
  11. How well did the tooth color match your expectations? (0 = not at all, 10 = perfectly)
  12. Do you feel that the use of digital software improved communication between you and your dentist?  
 Yes  
 No
  13. On a scale from 0 to 10, how satisfied are you with the final aesthetic result?
  14. On a scale from 0 to 10, how satisfied are you with the final functional result?
  15. To what extent did the final results meet your expectations?  
 Fully  
 Mostly  
 Partially  
 Not at all
  16. Overall, how much do you like your smile now? (0 = not at all, 10 = completely)

### 2.7. Statistical Analysis

Data were recorded and analyzed in a Microsoft Excel spreadsheet (Microsoft Excel for MacOS 16.95.3). The mean and standard deviation were calculated for each variable. Differences between pre- and post-treatment values were assessed using a paired t-test, with each patient serving as the statistical unit. All statistical analyses were performed with a significance level set at 0.05.

## 3. Results

Five adult patients, previously treated with clear aligners (Invisalign, Align Technology) and feldspathic veneers, were asked to complete the questionnaire and were included in this study. The mean age was 26.6 years. Four out of five patients were female, and none of the patients were smokers. All required minimally invasive prosthetic treatment for aesthetic reasons. In addition, following aesthetic and functional evaluations, all patients agreed to undergo aligner therapy prior to prosthetic restorations. All interviewed patients expressed a desire for a natural-looking smile. Four out of five preferred a natural tooth color, while one female patient requested a brighter, whiter shade. When asked to rate their smile aesthetics and function on a scale from 0 to 10 before treatment, the mean values were 4.8 (range: 4 to 6) and 6.6 (range: 5 to 8), respectively. After reviewing the pre-visualization of the newly designed smile in both 2D and 4 K video formats, patients rated the aesthetic outcomes with a mean score of 7.8 for the 2D preview and 9.2 for the 4 K video. Following the digital pre-visualization, all patients declared complete satisfaction with the proposed result. Similarly, after the mock-up application, the mean self-reported scores were 9.4 for tooth shape and 9.2 for color. All patients agreed that digital technologies were very helpful in understanding the upcoming treatment steps, and most reported that their initial expectations were completely met. The average total treatment time, including aligner therapy, was 11.6 months. When patients were asked again to rate their smile aesthetics and function following the full treatment, the mean scores were 9.8 (range: 9 to 10) for aesthetics and 9.4 (range: 8 to 10) for function. The improvements from baseline were statistically significant: 5.0 points for aesthetics ( $p = 0.001$ ) and 2.8 points for function ( $p = 0.002$ ). All patients reported complete satisfaction with the outcome, with a mean overall satisfaction score of 9.8. All the results are summarized in Table 1.

**Table 1.** Overall results.

Question	Result
Mean age	26.6 years
Reason for treatment	All for aesthetic reasons
Pre-treatment smile aesthetics (0–10)	4.8 (range: 4–6)
Pre-treatment function (0–10)	6.6 (range: 5–8)
Accepted aligner therapy	All accepted
Smile style preference	All preferred natural-looking smile
Tooth color preference	4 natural, 1 super white
2D preview rating (0–10)	7.8
3D preview rating (0–10)	9.2
Satisfaction with proposed outcome	All very satisfied
Tooth shape expectation match (0–10)	9.4
Tooth color expectation match (0–10)	9.2
Post-treatment smile aesthetics (0–10)	9.8 (range: 9–10)
Post-treatment function (0–10)	9.4 (range: 8–10)
Expectation fulfillment	Most completely met
Overall smile satisfaction (0–10)	10

#### 4. Discussion

This study aimed to evaluate patients' perceptions of smile aesthetics and function before and after an interdisciplinary, digitally planned treatment involving clear aligners and minimally invasive ceramic veneers. The research question was to evaluate whether the patients' perceptions of aesthetic and function increase with the pre-visualization of the final smile using 2D and 3D software, in patients treated with aligner therapy and minimally invasive prosthetic restorations. The findings highlight a significant improvement in both self-perceived smile aesthetics and oral function, with patients reporting high satisfaction post-treatment. The use of pre-visualization tools, particularly AI-powered video previews, was considered instrumental in setting realistic expectations and improving patient understanding and acceptance of the treatment plan.

The digital tools employed—especially exocad's Smile Creator and TruSmile—leveraged artificial intelligence to simulate a dynamic, realistic version of the patient's future smile [12,13]. This 4 K video-based preview allowed patients to visualize the functional and emotional expression of their anticipated outcome, enhancing confidence in the proposed treatment. Patients rated the AI-generated preview higher (mean: 9.2/10) than static 2D designs (mean: 7.8/10), reinforcing the added value of advanced simulation technologies in aesthetic dentistry. These tools enabled more accurate interdisciplinary planning and fostered improved communication between dentist and patient, consistent with previous findings by Coachman & Paravina [7] and Cervino & co-authors [9].

Statistically significant improvements were observed in both aesthetic (mean difference: +5.0,  $p = 0.001$ ) and functional outcomes (mean difference: +2.8,  $p = 0.002$ ). These results support the role of clear aligner therapy not only in orthodontic correction but also in optimizing the pre-prosthetic condition of teeth. Pre-restorative orthodontic movements created space and alignment that allowed for conservative tooth preparation—an outcome aligned with recent studies emphasizing minimally invasive protocols [5,10]. This sequence enabled guided no-prep or minimally invasive preparations based on mock-ups derived from the digital design. Such an approach helps preserve enamel and soft tissue integrity, enhancing long-term prosthetic success [2,3]. Venezia et al. [4] also highlighted the advantages of prosthetically guided orthodontics in achieving aesthetic harmony, a strategy mirrored in this study.

All patients received feldspathic veneers following orthodontic alignment. Feldspathic veneers are widely regarded as the gold standard for achieving superior aesthetic outcomes due to their exceptional optical properties, including translucency, light reflection, and color stability, which closely mimic natural enamel [14]. Compared to other restorative materials such as lithium disilicate or composite resins, feldspathic ceramics allow for more precise layering and characterization, enabling the clinician to achieve highly individualized and natural-looking results, especially in the anterior aesthetic zone [14].

Importantly, all patients preferred a natural smile over a hyper-aesthetic one, echoing a broader cultural shift toward subtle enhancements [15]. Most participants indicated that the digital mock-ups and AI previews were crucial to understanding the process and visualizing the outcome, which they found to be realistic and encouraging.

The findings of this study are consistent with those reported in previous research [16,17]. Digital pre-visualization enhances diagnostic accuracy and supports more comprehensive treatment planning. It may also serve as a valuable tool for improving patient motivation and helping patients recognize key aesthetic features, thereby fostering a preference for more natural-looking outcomes [17]. These software applications may offer significant potential in education, clinical training, and everyday dental practice.

A key strength of this study lies in demonstrating that the orthodontic treatment was strategically planned based on a pre-visualization of the final prosthetic outcome. This interdisciplinary approach enables minimally invasive tooth preparation, thereby reducing the biological cost of the restorations. Relying solely on prosthetic treatment would have required more invasive procedures, while exclusive orthodontic treatment may not have achieved the desired aesthetic outcomes. The combined use of orthodontics and veneers resulted in balanced, patient-centered outcomes. Naturally, treatment planning must always be individualized, taking into account the patient's initial expectations and specific clinical conditions. All patients consented to the orthodontic treatment after understanding the associated benefits, despite the higher costs involved.

This study underscored the value of integrating AI-driven visualization tools with aligner orthodontics and modern veneer techniques. As digital technology becomes increasingly precise, the ability to personalize smile designs, enhance communication, and deliver predictable aesthetic and functional outcomes will define the future of aesthetic dentistry.

The perception of aesthetics and function was assessed only using a set of 16 questions (subjective measures). To the best of the authors' knowledge, this is the first study to utilize the proposed questionnaire. A limitation of the present investigation is the lack of prior validation of the questionnaire in the existing literature. In addition, no sample size calculation was performed. Nevertheless, 16 questions should be adequate for the purposes of this preliminary evaluation. Further randomized controlled trials, with longer follow-up, are necessary to confirm these findings.

## 5. Conclusions

Patients undergoing a digitally planned, interdisciplinary approach involving clear aligners and feldspathic veneers reported high satisfaction with the final aesthetic and functional results. AI-based pre-visualization tools significantly contributed to treatment understanding and acceptance. The combination of clear aligner therapy and mock-up-guided veneer preparation allowed for minimally invasive, tissue-preserving procedures, offering predictable and natural-looking outcomes.

**Author Contributions:** Conceptualization, M.T. and M.S.; methodology, M.T.; software, M.A.; validation, S.M.M. and M.P.; formal analysis, M.S.; investigation, M.T. and R.L.; resources, M.A.; data curation, S.M.M.; writing—original draft preparation, C.C.; writing—review and editing, C.C.; su-

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**Funding:** exocad GmbH provided the orthodontic treatment to the participants.

**Institutional Review Board Statement:** Ethics committee approval was not requested due to the qualitative nature of the research. The data were evaluated at the Department of Medicine, Surgery, and Pharmacy, University of Sassari, Italy. The 2013 Helsinki Declaration and the Good Medical Practice principles were adhered to. Medical data were anonymized so that patients could not be identified.

**Informed Consent Statement:** All the patients signed an informed consent for the data acquisition and treatment execution. In addition, according to the European laws, patients also gave consent for photo and video recording, immediately before acquisition, for compliance with the General Data Protection Regulation (GDPR).

**Data Availability Statement:** The data can be made available on request to the authors.

**Conflicts of Interest:** Two of the authors (M.T. and R.L.) are key opinion leaders for exocad GmbH, and one author (M.A.) is an employee of the company. However, the authors declare that this research was conducted independently, without any commercial or financial influence from exocad GmbH. The company had no role in the design, execution, data interpretation, or writing of this study. The authors declare no other conflicts of interest related to this work.

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