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Complete Digital Workflow to Rectify the Angled Adjacent Dental Implants- An Advance Dental Approach

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ABSTRACT:

The restoration of angled adjacent dental implants poses significant challenges in achieving both aesthetic and functional outcomes. This article describes a complete digital workflow that addresses these challenges, offering a precise and efficient method for rectifying implant angles. By leveraging advanced digital tools, including computer-aided design and computer-aided manufacturing (CAD-CAM), this approach ensures the accurate fabrication and delivery of implant-supported restorations. The process includes modifying scan posts for accurate digital acquisition, using zirconia for restoration fabrication, and implementing a combined extraoral and intraoral cementation protocol.

Keywords: Angled dental implants, Digital workflow, CAD-CAM in dentistry, Implant-supported restorations, Zirconia restorations, Scan post modification, Intraoral cementation, Extraoral cementation, Implant angle rectification.

1. Introduction

Angled adjacent dental implants, where implants are placed at non-parallel or irregular angles in relation to each other, present a unique set of challenges for dental professionals[1]. Achieving the desired aesthetic and functional outcomes in such cases can be particularly difficult due to the complex anatomical considerations and the precise alignment required for successful implant restorations[2] (Annexure 1).

Challenges with Angled Adjacent Implants

One of the primary issues with angled adjacent implants is ensuring that the final prosthesis looks natural and functions correctly. When implants are not perfectly aligned, it can lead to a number of complications:

- **Aesthetic Concerns:** Misaligned implants can cause the final restoration to appear uneven or unnatural, which is particularly problematic in the anterior region where aesthetics are paramount[3].
- **Functional Issues:** Implants that are not properly aligned can compromise occlusion, leading to problems with chewing, speaking, and overall comfort[4]. In some cases, improper alignment can also cause stress on the implants, increasing the risk of mechanical failure or bone loss over time.
- **Prosthetic Fit:** Achieving a precise fit for the prosthesis is more challenging when implants are placed at different angles[5]. Traditional impression techniques may not accurately

capture the spatial relationships between the implants, leading to a poor fit and requiring additional adjustments.

Limitations of Traditional Methods

Traditional methods for correcting the angles of adjacent implants typically involve manual adjustments during the impression-taking and prosthesis fabrication stages[6]. These methods are often time-consuming, labor-intensive, and prone to human error. Common issues include:

- **Impression Distortion:** Conventional impression materials and techniques can sometimes distort, particularly when capturing complex geometries like angled implants[6]. This can lead to inaccuracies in the final prosthesis.
- **Manual Fabrication Errors:** In traditional workflows, much of the prosthesis design and fabrication is done manually[7,8]. This can result in inconsistencies and errors, especially when dealing with complex cases involving multiple implants at different angles.
- **Time and Resource Intensive:** Correcting angled implants using traditional methods often requires multiple appointments, extensive chair time, and repeated adjustments, which can be frustrating for both the patient and the clinician[8].

Advancements with Digital Dentistry

The advent of digital dentistry has revolutionized the approach to implant restorations, providing new opportunities to enhance precision, efficiency, and predictability. Digital workflows, particularly those involving CAD-CAM technology, have become increasingly popular in addressing the challenges associated with angled adjacent implants[9].

- **Digital Scanning:** High-resolution digital scanners, including intraoral scanners and cone-beam computed tomography (CBCT) devices, allow for precise capture of the implant positions and angles. Digital impressions eliminate the risk of material distortion and provide a highly accurate digital model of the patient's oral anatomy[10].
- **CAD (Computer-Aided Design):** Once the digital scan is complete, the data is imported into CAD software, where the prosthesis is designed[11]. The software allows for precise manipulation of the design, accommodating the unique angles of the implants. This digital design process ensures that the final restoration will have the correct contours, fit, and occlusal alignment.
- **CAM (Computer-Aided Manufacturing):** The digitally designed prosthesis is then fabricated using CAM technology, such as milling or 3D printing[12]. This process is highly accurate and consistent, producing restorations with superior fit and finish compared to those fabricated using traditional manual methods.
- **Efficiency and Predictability:** Digital workflows streamline the entire process, reducing the time required for both the clinician and the patient. The precision of digital tools minimizes the need for adjustments and remakes, leading to more predictable outcomes and higher patient satisfaction[11,12].

The Digital Workflow for Rectifying Angled Adjacent Implants (Annexure2)

This article explores a comprehensive digital workflow that integrates digital scanning, CAD-CAM technology, and advanced cementation protocols to rectify angled adjacent dental implants. By leveraging these digital tools, clinicians can achieve precise implant restorations that meet both aesthetic and functional requirements.

- **Digital Acquisition:** The process begins with accurate digital scanning, made possible by modifying the proximal surface of a scan post for correct adaptation[14]. This modification

allows for the precise capture of the implant angles in a single scan, forming the foundation for the rest of the digital workflow.

- **CAD-CAM Fabrication:** The acquired data is used to design and fabricate the restoration in a zirconia material. This step involves detailed planning in the CAD software, ensuring that the prosthesis will fit perfectly onto the angled implants. CAM technology then mills the restoration with high precision[15].
- **Delivery Protocol:** The final step involves a combined extraoral and intraoral cementation process, ensuring the secure and accurate placement of the restoration. This approach reduces the risk of complications and enhances the long-term success of the implant[16].

Digital Acquisition

The first step in the digital workflow involves the accurate acquisition of the implant positions. A common challenge with angled adjacent implants is the difficulty in capturing precise digital scans due to the proximity and angles of the implants[17]. To overcome this, the proximal surface of the scan post is modified, allowing for correct adaptation and alignment. This modification ensures that the digital scan captures the exact positions and angles of the adjacent implants in a single step, providing a reliable foundation for the subsequent design and fabrication processes.

CAD-CAM Design and Fabrication

Once the digital scan is acquired, the data is imported into CAD software, where the definitive implant-supported restorations are designed. The focus during this stage is on creating screw-retained, splinted restorations that accommodate the unique angles of the implants[18].

Zirconia is chosen as the material for these restorations due to its superior strength, durability, and aesthetic qualities. The CAD software allows for the meticulous design of the restorations, ensuring that they will fit precisely onto the angled implants. Once the design is finalized, the restorations are milled using CAM technology, resulting in high-quality, custom-made restorations that are ready for delivery.

Delivery Protocol: Combined Extraoral and Intraoral Cementation

The two-step cementation process for CAD-CAM fabricated restorations on angled adjacent dental implants is a critical component of the digital workflow. This protocol, which combines extraoral and intraoral techniques, is designed to enhance the accuracy of the final fit and minimize the risks that can arise during cementation, such as peri-implantitis, poor fit, or mechanical failures[19]. Here's a detailed breakdown of each step:

1. Extraoral Cementation[19,20]

Controlled Environment:

- **Precision and Control:** The initial cementation is carried out outside the patient's mouth, in a controlled environment. This setting allows the dental professional to meticulously seat the restoration onto the implant without the challenges posed by the intraoral environment, such as limited visibility, patient movement, or the presence of saliva.
- **Reducing Excess Cement Risks:** By performing this step extraorally, the clinician can carefully manage the amount of cement used, ensuring that excess cement does not accumulate around the implant-abutment interface. Excess cement is a well-known risk factor for peri-implantitis, an inflammatory condition that can lead to implant failure if not properly managed.

Proper Seating and Verification:

- **Ensuring Proper Seating:** During extraoral cementation, the clinician can ensure that the restoration is fully seated onto the implant abutment. This involves checking that the restoration is correctly aligned with the implant and that there is no gap or misfit.

- **Verification:** After seating the restoration, the clinician can verify the fit and retention before moving forward. This verification step is crucial because it allows for any necessary adjustments to be made in a controlled environment, without the constraints of intraoral conditions.

Excess Cement Removal:

- **Cleaning and Polishing:** Once the restoration is seated, any excess cement can be easily removed and the restoration can be polished to ensure a smooth finish. This step is important for both the aesthetic outcome and the long-term health of the peri-implant tissues.

2. Intraoral Cementation[19,21]

Final Placement and Adjustments:

- **Transfer to the Oral Cavity:** After the extraoral cementation process is complete, the restoration is transferred to the patient's mouth. During this phase, the restoration is carefully placed onto the implants, ensuring that it aligns perfectly with the surrounding teeth and occlusion.
- **Final Adjustments:** Intraoral cementation allows for real-time assessment of the restoration's fit, occlusion, and aesthetics. The clinician can make any necessary adjustments to the restoration or the cementation process to ensure that the final fit is secure and comfortable for the patient. This step is crucial for fine-tuning the restoration to the patient's unique oral environment.

Secure and Accurate Fit:

- **Enhanced Stability:** The intraoral cementation ensures that the restoration is securely and accurately fitted onto the implants. By performing this final step in the mouth, the clinician can confirm that the restoration is stable and that there is no movement or misalignment.
- **Long-Lasting Results:** The combination of extraoral precision and intraoral adjustments contributes to a stable and durable restoration. The secure fit reduces the likelihood of complications, such as loosening or shifting of the restoration over time.

Minimizing Risks:

- **Preventing Peri-Implantitis:** One of the primary goals of this two-step process is to prevent peri-implantitis by ensuring that no excess cement is left in the peri-implant area. By removing excess cement during the extraoral step and verifying the fit intraorally, the risk of cement-induced peri-implantitis is significantly reduced.
- **Optimizing Occlusion:** The intraoral step allows for the final assessment of occlusion, ensuring that the restoration does not interfere with the patient's bite and that the forces on the implant are evenly distributed. This is essential for preventing undue stress on the implants, which could lead to mechanical failure or bone resorption. The two-step cementation process, combining extraoral and intraoral techniques, is a sophisticated approach that maximizes the accuracy of implant-supported restorations. By separating the cementation into two distinct phases, clinicians can take full advantage of a controlled environment to ensure proper seating and cement removal before finalizing the fit intraorally. This method not only enhances the precision and stability of the restoration but also significantly reduces the risks associated with traditional cementation methods, leading to better long-term outcomes for patients with angled adjacent dental implants.

2. Discussion

The complete digital workflow for rectifying angled adjacent dental implants represents a significant advancement in dental implantology, offering several distinct advantages over

traditional methods[22]. Here's a detailed exploration of these benefits, as well as considerations regarding the adoption of this approach:

Advantages of the Complete Digital Workflow

1. High Precision in Design and Fabrication

CAD-CAM Technology:

- **Accuracy:** Computer-Aided Design and Computer-Aided Manufacturing (CAD-CAM) technology is at the core of the digital workflow. The precision of CAD-CAM ensures that restorations are designed with exacting accuracy, taking into account the unique angulations and positions of adjacent implants. This leads to restorations that fit precisely, minimizing the need for adjustments and ensuring a proper seal at the implant interface.
- **Customized Solutions:** CAD-CAM allows for the creation of highly customized restorations that are tailored to the patient's specific anatomical and functional needs. This level of customization is difficult to achieve with traditional methods, where manual fabrication can introduce inconsistencies.

Digital Scanning and Modifications:

- **Enhanced Scan Accuracy:** The use of a modified scan post, which adapts to the unique angulations of adjacent implants, enables a highly accurate digital scan. This modification ensures that the digital impressions reflect the true spatial relationships of the implants, leading to a more precise digital model for restoration design.
- **Single-Step Capture:** The ability to capture the implant positions in a single step reduces the potential for errors that can arise from multiple scans or impressions. This streamlines the workflow and enhances the overall accuracy of the process.

2. Improved Functional and Aesthetic Outcomes

Functional Benefits:

- **Optimal Occlusion:** The precision of the digital design process ensures that the occlusal surfaces of the restorations are correctly aligned with the opposing teeth, distributing bite forces evenly. This reduces the risk of implant overload, which can lead to mechanical failure or bone resorption.
- **Long-Term Stability:** The accurate fit of the restorations enhances their stability, reducing the likelihood of complications such as loosening or shifting over time. This contributes to the long-term success of the implants and the satisfaction of the patient.

Aesthetic Benefits:

- **Natural Appearance:** The digital design allows for the creation of restorations that closely mimic the natural teeth in terms of shape, color, and contour. This is particularly important in the anterior region, where aesthetics are a primary concern.
- **Consistency:** CAD-CAM technology ensures consistent results, with each restoration being fabricated to the same high standards. This consistency is difficult to achieve with traditional methods, where manual variations can affect the final outcome.

3. Enhanced Accuracy and Predictability

Combined Cementation Protocol:

- **Minimizing Risks:** The two-step cementation process, which combines extraoral and intraoral techniques, significantly enhances the accuracy of the final fit. By performing initial cementation outside the mouth, clinicians can better control the process, reducing the risk of excess cement and ensuring a precise fit.

- **Predictable Outcomes:** The digital workflow, with its emphasis on precision and accuracy, leads to more predictable outcomes. This predictability reduces the need for remakes or extensive adjustments, saving time for both the clinician and the patient.

Considerations for Adoption

1. Investment in Advanced Technology

Initial Costs:

- **High Upfront Investment:** Adopting a complete digital workflow requires significant investment in advanced technology, including intraoral scanners, CAD-CAM software, and milling machines. These tools are essential for implementing the workflow, but they come with a substantial initial cost.
- **Ongoing Expenses:** In addition to the upfront costs, there are ongoing expenses associated with maintaining the equipment, updating software, and possibly licensing fees for CAD-CAM programs.

2. Training and Expertise

Need for Specialized Training:

- **Learning Curve:** The shift from traditional to digital methods involves a learning curve for dental professionals. Clinicians must acquire new skills to effectively use digital tools, including mastering CAD-CAM software and understanding the nuances of digital scanning and fabrication.
- **Continued Education:** As digital dentistry continues to evolve, ongoing education and training are necessary to stay current with the latest advancements. This may involve attending workshops, courses, or certifications in digital implantology.

Enhanced Team Collaboration:

- **Interdisciplinary Approach:** The digital workflow often requires close collaboration between the clinician, dental technician, and software specialists. Effective communication and teamwork are essential to ensure that each step of the process is executed correctly.

Long-Term Benefits

Patient Satisfaction:

- **Higher Quality Restorations:** The precision and customization offered by the digital workflow lead to restorations that meet the highest standards of fit, function, and aesthetics. Patients are likely to appreciate the improved comfort and appearance of their restorations, leading to higher satisfaction rates.
- **Reduced Chair Time:** The streamlined digital process often reduces the number of appointments and the duration of each visit, making the experience more convenient for patients.

Clinical Success:

- **Improved Outcomes:** The accuracy and predictability of the digital workflow contribute to better clinical outcomes, including lower rates of implant failure and complications. This not only benefits the patient but also enhances the reputation of the practice.
- **Cost-Effectiveness:** While the initial costs of adopting digital technology are high, the long-term benefits include reduced remakes, fewer adjustments, and improved patient retention. These factors contribute to the overall cost-effectiveness of the digital approach. The complete digital workflow for rectifying angled adjacent dental implants represents a major advancement in implant dentistry. (Annexure 3) While the adoption of this approach requires significant investment in technology and training, the benefits in terms of precision, efficiency, and patient satisfaction make it a worthwhile endeavor. As digital

dentistry continues to advance, the advantages of this workflow are likely to become even more pronounced, setting a new standard for implant restoration techniques.

3. Conclusion

Rectifying angled adjacent dental implants is a complex challenge that requires a precise and efficient approach. The complete digital workflow outlined in this article offers an advanced solution, leveraging the power of CAD-CAM technology to achieve optimal results[3,6,7]. By modifying scan posts for accurate digital acquisition, utilizing zirconia for restoration fabrication, and implementing a combined cementation protocol, this approach ensures the successful correction of implant angles, leading to improved patient outcomes.

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23. Annexure 1

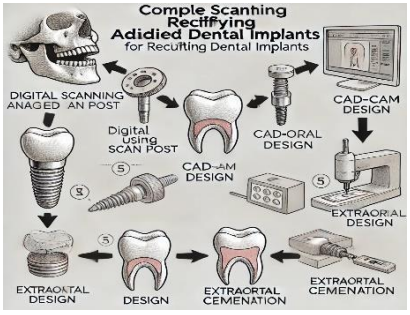
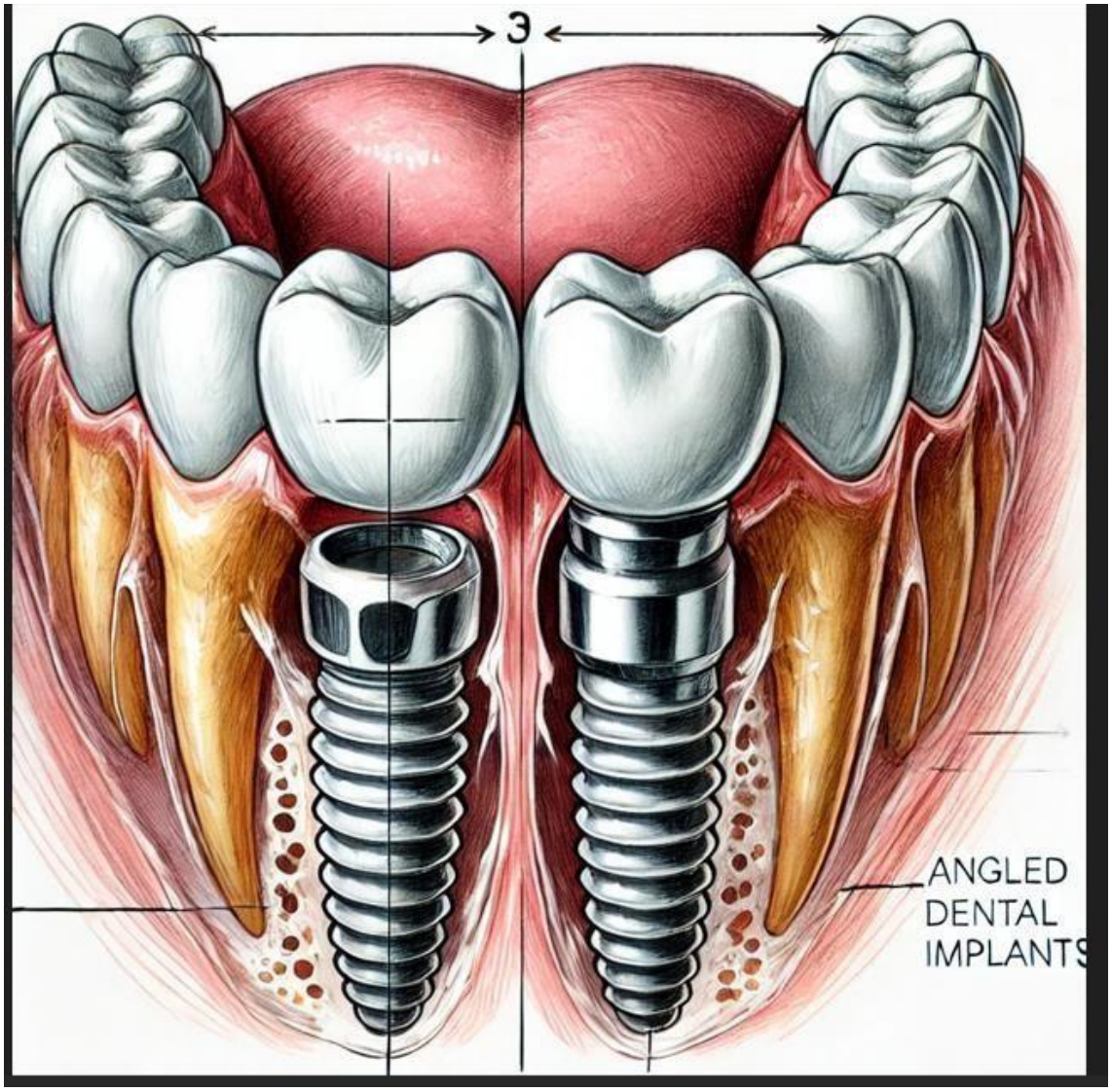


Diagram illustrating the complete digital workflow for rectifying angled adjacent dental implants. It represents the key steps in a minimalistic and clear format.



Two angled dental implants, each at a different angle

Step	Description
1. Digital Scanning	**Use a modified scan post to capture accurate digital impressions of angled adjacent implants.**
2. CAD-CAM Design	**Design the implant-supported restoration using CAD software, accounting for the implant angles.**
3. Milling	**Fabricate the restoration from zirconia material using CAM technology.**
4. Extraoral Cementation	**Perform initial cementation outside the mouth to ensure proper seating and minimize excess cement.**
5. Intraoral Cementation	**Place the restoration in the mouth and make final adjustments to ensure a secure and accurate fit.**

Annexure 2 table summarizing the complete digital workflow for rectifying angled adjacent dental implants:

Annexure 3 Flow chart- complete digital workflow to rectify angled adjacent dental implants, the process generally involves several key steps

- **Initial Assessment and Imaging**
  - **3D CBCT Scan: Obtain a detailed 3D scan to assess the bone structure and implant positioning.**
  - **Digital Impressions: Capture precise digital impressions of the dental arches.**
- **Treatment Planning**
  - **CAD Software: Use computer-aided design (CAD) software to plan the ideal implant placement, considering the angulation and adjacent teeth.**
  - **Virtual Implant Placement: Simulate the implant placement in the software to ensure proper positioning.**
- **Surgical Guide Design**
  - **Design Surgical Guide: Create a custom surgical guide using CAD software, which will aid in precise placement of the implants.**
  - **3D Printing: Manufacture the surgical guide with a 3D printer.**
- **Implant Placement**
  - **Surgical Procedure: Place the implants using the surgical guide to achieve the planned angulation and position.**
- **Restoration Planning**
  - **Digital Scans Post-Surgery: Capture digital impressions after implant placement.**
  - **Virtual Tooth Design: Design the final restoration (crown, bridge) in CAD software, ensuring it fits accurately with the implants.**
- **Fabrication of Restoration**
  - **Milling or 3D Printing: Manufacture the restoration using a milling machine or 3D printer based on the CAD design.**
- **Final Placement and Adjustment**
  - **Fit and Adjust Restoration: Place and adjust the final restoration on the implants, ensuring proper occlusion and esthetics.**
- **Post-Treatment Evaluation**
  - **Final Imaging: Obtain follow-up imaging to verify the success of the implant placement and restoration.**