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Protocol workflow for immediate loading protocol under dynamic navigation technique

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Abstract:
Aim: To assess the marginal fit and occlusal assessment of the crown after implant placement under dynamic navigation technique. **Materials and methods:** This study was conducted in the Department of Implantology, Saveetha Dental College, Chennai and involved an in-vitro analysis of twenty implants placed by a single operator using dynamic navigation. The crowns were fabricated in advance using 3shape software. Sequential drilling and implant placement were performed under dynamic navigation, ensuring proper calibration. The primary outcome measures included accuracy parameters such as bucco-lingual deviation, apico-coronal deviation, mesio-distal angulation, and apical deviation. Additionally, the vertical marginal adaptation of the crowns was assessed, while secondary outcome measures included a questionnaire regarding the crown's adaptation. **Results:** The accuracy of implant placement was measured using the EVALUNAV software. There was a statistically significant difference in the mesio-distal angulation, whereas no significant difference was seen in buccolingual, mesiodistal and apical coronal deviation. **Conclusion:** Digital workflows in implant dentistry enhance precision, efficiency, and treatment outcomes. Technologies like CBCT and intraoral scanning improve planning and custom guide creation, leading to better implant placements and patient satisfaction. The benefits of static and dynamic navigation are significant, while 3D analysis offers a path for more accurate assessments of marginal fit. Embracing these innovations streamlines workflows and improves patient communication, supporting the ongoing integration of digital technologies for superior clinical outcomes.
Keywords: Dynamic navigation, Immediate loading, Guided implant surgery

Introduction:

Dental Implants have transformed the approach of prosthetic rehabilitation. Although they are the most sought after treatment modality, they have their own set of risk factors, mechanical and biological complications. The complications include surgical complications like hemorrhage and nerve injuries, prosthetic complications like obstacles faced during loading a restoration, improper angulation of the implant placed, and aesthetic complications like resorption of the buccal plate ultimately resulting in dehiscence. Prosthetically driven dental implant placement is considered optimal for minimizing biological and mechanical complications. Achieving this requires a thorough preoperative assessment of available bone and precise alignment of the implant position with the intended final restoration. Computer-assisted surgery (CAS) has emerged as a valuable tool to reduce discrepancies between planned and actual implant placement. Two main CAS approaches are utilized: dynamic CAS, which employs navigation systems that provide real-time tracking to guide the clinician to the predefined implant position, and static CAS, which uses surgical guides to replicate the virtual implant position. In dynamic CAS, implants are placed using a freehand technique, while a computer program offers real-time feedback on the drill's position relative to the patient’s jaw. Conversely, static CAS relies on a rigid stent with sleeves to direct drilling and implant insertion accurately. These advancements in CAS facilitate improved surgical outcomes by enhancing the precision of implant placements.Dynamic navigation (DN) system is a semi-robotic cutting-edge technique that has emerged in the rapidly developing field of dental implantology. It combines advanced imaging techniques such as Cone Beam Computed Tomography (CBCT) in conjunction with computer software to generate a virtual three-dimensional (3D) model of the oral anatomy of the patient. The complications faced during the placement of the implant can be overcome with the help of this new technique. In a study by Dotia et al, dynamic navigation was used for a direct sinus lift and simultaneous implant placement surgery when adequate bone was absent in the posterior maxilla.[1] During implant placement procedures, dynamic surgical navigation tracks the position of the dental drill and the patient in real time using a combination of surgical instruments, three-dimensional images, and optical positioning systems. Dynamic navigation systems display images on computers. Dynamic navigation enables the drill to be viewed through any anatomical structure or trans-alveolar. As a result, it eliminates the possibility of iatrogenic damage to anatomical structures and allows for adjustments to the intraoperative surgical treatment regimen.[2] Dynamic navigation can be used on patients with limited mouth opening because it does not require 3D stents, unlike static computer-guided surgery, which requires stents to guide implant placement. Any drill system or implant can be utilized for dynamic navigation. This aids in a more accurate placement of the implant.[3,4] In previous studies, the accuracy of implant placement dynamic navigation technique has been compared to static guides and a novel hybrid technique which involves an amalgamation of static guide and dynamic navigation has also been described.[5,6]

Immediate prosthetic rehabilitation following implant placement allows for prompt restoration of function and aesthetics, significantly enhancing patient satisfaction. This approach is particularly effective for single-tooth replacements and in anterior sites where aesthetics are crucial. Ideal candidates typically exhibit sufficient bone quality and stable soft tissue conditions, with careful surgical techniques such as flapless methods and guided surgery minimizing trauma and promoting optimal healing. The use of custom-made provisional restorations on the same day as implant placement helps maintain soft tissue contours and serves as a functional placeholder until the final restoration can be fitted. Studies show that immediate loading can achieve long-term success comparable to delayed methods when appropriate protocols are followed. Thus, immediate prosthetic rehabilitation not only improves the overall patient experience but also supports favorable clinical outcomes.

This study aims to assess the marginal fit and accuracy of the prosthesis after pre planning the implant placement with the help of dynamic navigation software.

1. Materials and methods:

2.1 Study Design: This in-vitro study was carried out at the Department of Implantology, Saveetha Dental College and Hospital in Chennai, in the Department of Implantology between October 2023 and April 2024. The Institutional Review Board of Saveetha Dental College and Hospital, Chennai approved the study protocol (Approval number: SRB/SDC/MSIMPLANT-2310/24/029).

2.2 Model Procurement: A patient who had both first mandibular molars missing was selected. The patient was subjected to Cone Beam Computed Tomography (*CareStream 9600, Onex Corporation, Rochester, New York, United States*) and intraoral scan *(TRIOS 5, 3shape, Copenhagen, Denmark)*. Ten models were printed in resin of the patient’s scan.

2.3 Implant Planning: The DICOM data (Digital Imaging and Communication in Medicine) and the STL (Standard Tessellation Language) files were uploaded into the Dynamic navigation software for prosthetically driven implant planning. The Dynamic navigation software used in this study was Navident (*Claronav, Canada*). The DICOM data and the STL files were merged using three point alignment within the software. The virtual mock-up of the missing teeth were carried out and the three dimensional position of the tooth was verified by the operator. Corresponding to the tooth position, the implant of proper dimensions are chosen and virtually planned with the software. 4.1 x 10 mm Bone Level Tapered (*Straumann, Waldenburg, Switzerland)* implants were planned in both the sites. (Figure 1, Figure 2)

2.4 Crown Fabrication: The output of the STL file was loaded in the 3shape software and the alignment of the implant on the STL file was done. The implant info file was loaded in the 3shape prosthetic design software. The ti-base abutments (*Straumann, Waldenburg, Switzerland)* were selected in the order form and crowns were designed. (Figure 3) The crowns were then printed (Dio, *probo*) in Polymethyl Methacrylate (PMMA) resin.

2.5 Implant Placement: The resin model was mounted on the mannequin head and the jaw trackers were attached in place. Prior to the operation, calibration and registration procedures were carried out. By calibrating each drill before drilling, the computer was able to determine the relationship between the surgical handpiece and the patient monitoring jaw tracker, as well as the relationship between drill position and actual anatomical structures. With the use of jaw trackers inserted into the model, the continuous motions were continuously recorded. Drill tags equipped with optical sensors were attached to handpieces, and these sensors were continuously monitored by stereo cameras that were optimized by an LED light panel. On the CBCT loaded into the software, trace points were chosen on neighboring teeth, and trace registration was completed by painting the tooth surface using the trace registration device. Post trace registration, the accuracy was evaluated by placing the stylus back on the tooth surface. Dynamic navigation operates via a triangulation process in which an LED light panel illuminates the optical sensors found in the drill tag attached to the surgical handpiece and the jaw tracker attached to the model in the mannequin head. The osteotomy site was prepped, the implant was implanted, and additional procedures were carried out with the patient's mouth visible to ensure precise implant placement while viewing a screen. (Figure 4)

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2.6 Outcome parameters

2.6.1 Assessment of accuracy post placement: A post operative Cone Beam Computed Tomography (CBCT) was taken and other parameters like the buccolingual deviation, mesiodistal deviation, apicocoronal deviation and mesiodistal angulation deviation were assessed using EVALUNAV, Navident software that is used for assessment of accuracy. (Figure 5, Figure 6)

2.6.2 Assessment of crown seating: As this is an in-vitro study and the resin model lacks a gingival counterpart, an abutment profile drill was used to remove any excess material around the implant for better seating of the abutment. After the placement of the implants the already planned Variobase abutment with the accurate collar height and abutment height was placed instead of the cover screw and the prefabricated PMMA crowns were placed on the abutment. (Figure 7) The marginal fit of the crowns were assessed clinically. The clinical verification was carried out by marking 5 questions on the Likert scale.

1. **Marginal Fit Quality**: How would you rate the quality of the marginal fit of the crown?
(1 - Very poor, 2 - Poor, 3 - Adequate, 4 - Good, 5 - Excellent)
2. **Gaps at the Margin**: How significant do you perceive any gaps at the crown margin after placement?
(1 - Very significant gaps, 2 - Significant gaps, 3 - Moderate gaps, 4 - Very less gap, 5 - No gaps)
3. **Contour Accuracy**: How accurately does the crown contour match the natural tooth structure?
(1 - Very inaccurately, 2 - Inaccurately, 3 - Moderately, 4 - Accurately, 5 - Very accurately)
4. **Interproximal Contact**: How well does the crown establish contact with adjacent teeth?
(1 - Very poorly, 2 - Poor, 3 - Adequate, 4 - Good, 5 - Very well)
5. **Retention and Stability**: How stable and retained does the crown feel after placement?
(1 - Very unstable, 2 - Unstable, 3 - Moderate, 4 - Stable, 5 - Very stable)

2.7 *Assessment under stereomicroscope:* The crowns were cemented using glass ionomer cement *(Shofu, Kyoto, Japan)*. And the vertical marginal gap was assessed using a stereomicroscope *(Leica, Wetzlar, Germany)* using 40X magnification. The seating was assessed on the buccal aspect at three random positions by measuring the gap between the finish line of the abutment and the crown margin at the crown abutment junction. The minute seating discrepancy was noted and analyzed between the right and left side. (Figure 8, Figure 9)

2.8 *Statistical analysis:* Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS), version 23. Descriptive statistics were employed to summarize and describe the features of the dataset. Additionally, a t-test was performed to assess the differences between group means. The analyses provided insights into the central tendencies and variations within the data, and the t-test results were used to determine the statistical significance of the observed differences.

2. **Results**

3.1 Accuracy analysis:

Deviation Type	Right Mandibular Molar (Mean ± SD)	Left Mandibular Molar (Mean ± SD)	p-Value (approx)
Buccolingual Deviation	0.541 ± 0.210 mm	0.447 ± 0.297 mm	0.45
Mesiodistal Deviation	0.728 ± 0.243 mm	0.750 ± 0.221 mm	0.81
Apico Coronal Deviation	1.180 ± 0.243 mm	1.235 ± 0.277 mm	0.57
Mesiodistal Angulation	2.555 ± 0.506 degree	2.790 ± 0.325 degree	0.03*

Table 1: Descriptive analysis of the various outcome parameters.

Points	Mean ± Standard Deviation	Significance
Mesial Point of Left Molar **Mesial Point of Right Molar**	0.19 ± 0.02 mm 0.31 ± 0.28 mm	0.00*
Central Point of Left Molar **Central Point of Right Molar**	0.21 ± 0.04 mm 0.33 ± 0.03 mm	0.00*
Distal Point of Left Molar **Distal Point of Right Molar**	0.20 ± 0.19 mm 0.30 ± 0.02 mm	0.00*

Table 2: Descriptive analysis of the vertical marginal gaps at the various points.

Marginal Fit Quality: How would you rate the quality of the marginal fit of the crown?	**0%**	**5%**	**20%**	**65%**	**10%**
Gaps at the Margin:How significant do you perceive any gaps at the crown margin after placement?	**0%**	**10%**	**25%**	**50%**	**15%**
Contour Accuracy:How accurately does the crown contour match the natural tooth structure?	**0%**	**0%**	**10%**	**55%**	**35%**
Interproximal Contact:How well does the crown establish contact with adjacent teeth?	**0%**	**0%**	**30%**	**65%**	**5%**
Retention and Stability:How stable and retained does the crown feel after placement?	**0%**	**5%**	**25%**	**60%**	**10%**

Table 3: Analysis of the questionnaire according to the likert scale.

3.1.1 Implant Placement Deviation (Table 1)

3.1.1.1 Buccolingual Deviation: The mean ± standard deviation (SD) of buccolingual deviation was calculated as 0.54 ± 0.21 mm for the right mandibular molar and 0.44 ± 0.29 mm for the left mandibular molar. There was no significant difference between the right and left mandibular molars.

3.1.1.2 Mesiodistal Deviation: For the right mandibular molar, the mean ± standard deviation (SD) of buccolingual deviation was determined to be 0.72 ± 0.24 mm, while for the left mandibular molar, it was 0.75 ± 0.22 mm. No significant difference was found between the right and left mandibular molars.

3.1.1.3 Apico Coronal Deviation: The buccolingual deviation mean ± standard deviation (SD) for the right mandibular molar was found to be 1.18 ± 0.24 mm, while for the left mandibular molar, it was found to be 1.23 ± 0.27 mm. There was no discernible difference between the right and left mandibular molars.

3.1.1.4 Mesiodistal Angulation: The mean deviation ± standard deviation (SD) of Mesiodistal Angulation was 2.555 ± 0.506 degrees for the right first Mandibular molar and 2.790 ± 0.325 degrees for the left first Mandibular molar. There was a significant difference noticed between both the groups.

3.1.2 Crown Deviation (Table 2)

3.1.2.1 Vertical Marginal Gap: The mean and standard deviation of the mesial point of the left and right molar was 0.19 ± 0.02 mm and 0.31 ± 0.28 mm, central point of the left and right molar was 0.21 ± 0.04 mm and 0.33 ± 0.03 mm, distal point of the left and right molar was 0.20 ± 0.19 mm and 0.30 ± 0.02 mm respectively. There was a significant difference seen in all the groups.

3.1.3 Analysis of the questionnaire (Table 3) The evaluation of the dental crown revealed several quality concerns. The marginal fit was rated at 10%, indicating poor adaptation, while gaps at the margin were considered moderately significant at 15%. Contour accuracy was rated at 35%, showing only a moderate match with the natural tooth. Interproximal contact with adjacent teeth was notably low at 5%, suggesting serious stability issues. Additionally, retention after placement was rated at 10%, highlighting concerns about the crown's security. These results emphasize the need for improvements in crown design and fitting processes to enhance performance and longevity.

3. **Discussion**

The implementation of a digital workflow in implant dentistry significantly enhances precision, efficiency, and predictability in treatment outcomes.[7] Utilizing advanced technologies such as Cone Beam Computed Tomography (CBCT) and intraoral scanning, clinicians can obtain detailed 3D imaging and accurate digital impressions of the patient's oral anatomy. These digital tools facilitate comprehensive treatment planning through specialized software that allows for virtual simulations and the design of custom surgical guides via CAD/CAM technology. As a result, guided surgeries can achieve more accurate implant placements, ultimately leading to improved patient satisfaction and reduced complication rates as well as operator comfort and time taken for the surgery.[8] The adoption of this digital approach not only streamlines workflows but also supports better communication with patients, reinforcing the growing importance of digitalization in contemporary dental practice. Static surgical guides are designed to enhance the precision of implant placement by providing a predetermined pathway for drill insertion, which can significantly reduce the risk of misalignment and improve the overall outcomes of the procedure. This enhanced precision can lead to improved aesthetics and function, ultimately contributing to higher patient satisfaction. Furthermore, the adoption of digital technologies in creating these guides has further refined their accuracy, making them an essential tool in modern implant dentistry.

Recent studies highlight the significant benefits of using static surgical guides for implant placement, particularly in enhancing the accuracy of prosthetic loading. This precision not only reduces the risk of misalignment but also leads to more favorable outcomes in terms of prosthetic fit and esthetics. Furthermore,

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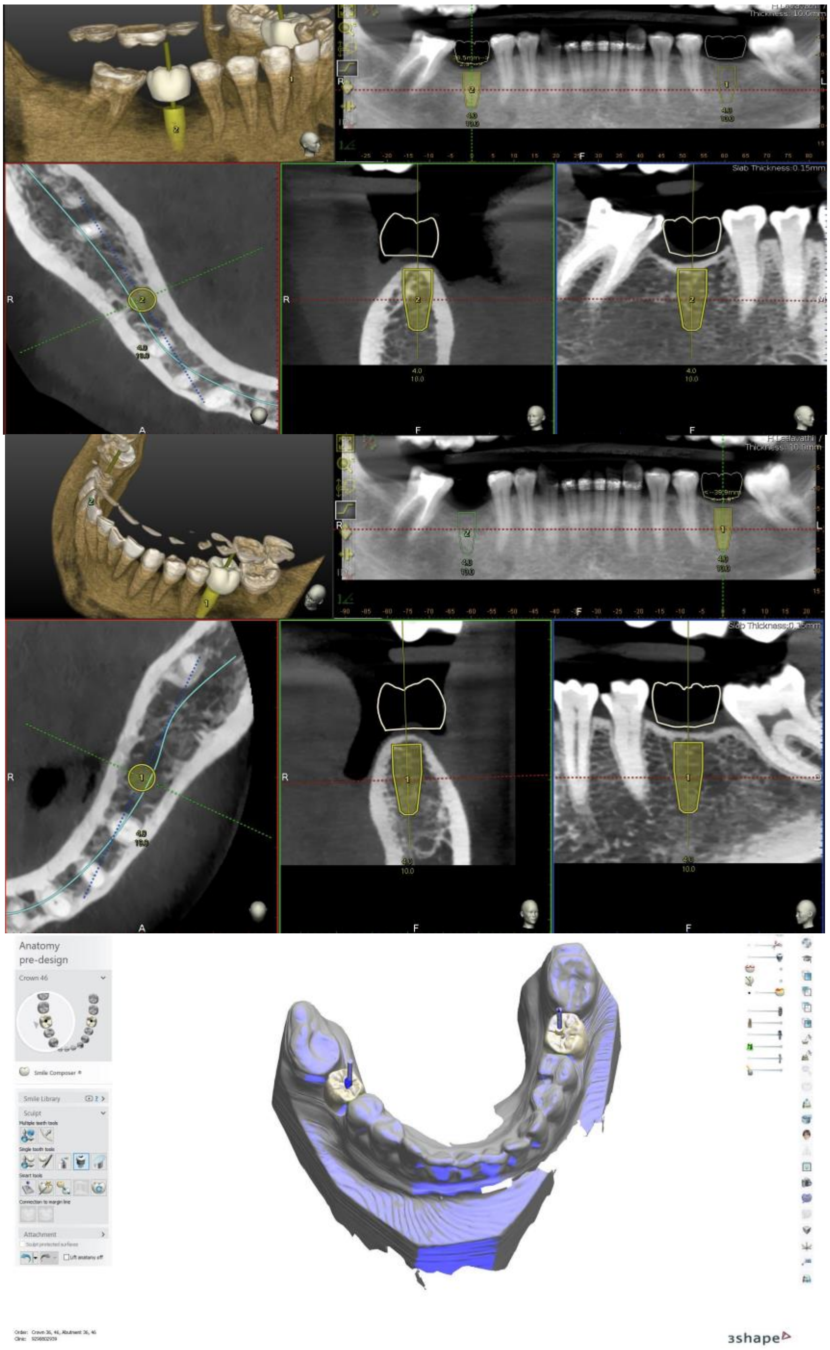
advancements in digital technology for guide fabrication have further refined this process, making static guides an invaluable tool in contemporary implant dentistry. By minimizing variability in implant placement, these guides contribute to higher patient satisfaction and successful long-term results.

Dynamic navigation has proven to have an upper hand when compared to the freehand implant placement as well.[9] Using a T-scan ensures balanced occlusion by measuring bite force distribution and timing. This helps identify premature contacts or excessive forces on the implant, which can lead to complications like bone loss or implant failure. The T-scan allows for precise adjustments to the prosthetic restoration, optimizing long-term implant stability and function by ensuring even load distribution across the teeth and implants during chewing and biting.[10] In a previous article, which studied about the implant prosthesis utilized T-Scan Novus to assess dynamic occlusal contact in implant occlusion, revealing that mandibular arch prostheses often fluctuate between high and low contact intensities, with a 10% contact percentage on implant crowns correlating with a protective occlusion that enhances load distribution and longevity.[11]

This study investigated the marginal fit of a crown for the implant that was preplanned using dynamic navigation software. The analysis of the right and left first mandibular molars indicated no significant differences in buccolingual, mesiodistal, and apicocoronal deviations. However, a statistically significant difference was observed in mesiodistal angulation deviation ($p < 0.05$), with the right first mandibular molar demonstrating a lesser deviation compared to the left. This variation may be attributed to the operator's right-handedness, which could influence the precision of implant followed by the crown placement. Similarly, a previous study indicated that more experienced postgraduates exhibited a more comprehensive understanding of angulation compared to undergraduates. The second and third quadrants were identified as the most challenging sites for accurately assessing angulation.[12] These findings underscore the importance of considering operator-related factors when evaluating outcomes associated with dynamic navigation techniques.

There is currently no consensus on acceptable marginal discrepancy levels in dental restorations, with some studies suggesting thresholds of 120 micrometers[13] or lower and others proposing 200 micrometers.[14] Most studies reported marginal gaps within this range, primarily using 2D analysis methods, which may limit the comprehensiveness of fit assessments. Alternative approaches, such as 3D analysis, could enhance accuracy and reliability, indicating that the reviewed studies may have low validity.[15]



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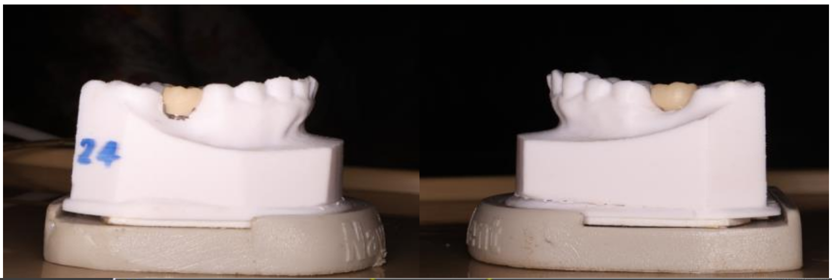

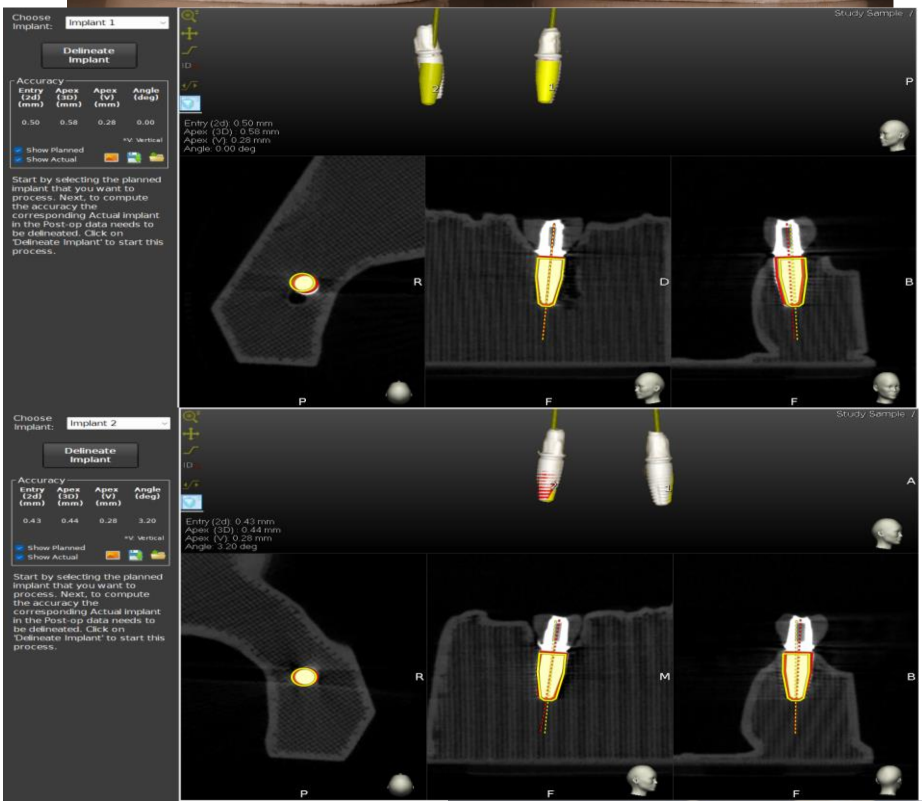

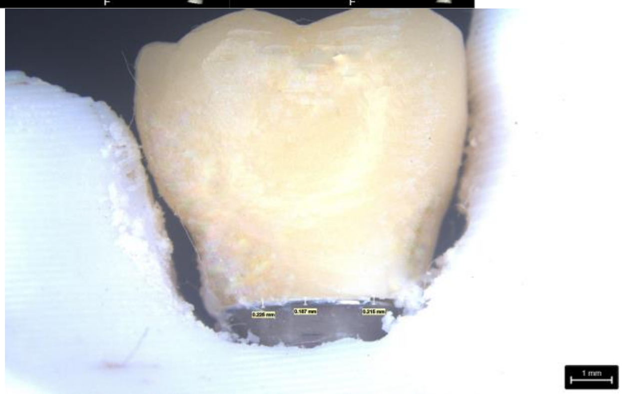

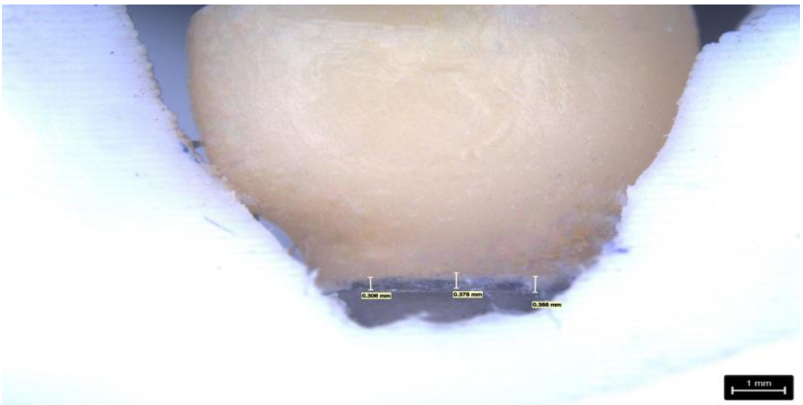

Figures:

1. Implant positioning and planning under the dynamic navigation software (Mandibular first molar 1)
2. Implant positioning and planning under the dynamic navigation software (Mandibular first molar 2)
3. Crown designing in 3Shape software
4. Sequence of calibration and drilling.

(A) Jaw tracker attached to the cast on the mannequin head, (B) Tracer tip calibration, (C) Drill tag attached to the hand piece, (D) Calibration of the drill for depth assessment, (E) Drilling sequence

5. Immediate crown cementation after implant placement.

(A) Mandibular first molar 1, (B) Mandibular first molar 2

6. EVALUNAV analysis of mandibular first molar 1 post placement.
7. EVALUNAV analysis of mandibular first molar 2 post placement.
8. Assessment of the microgaps in mandibular first molar 1 post placement using stereomicroscopy.
9. Assessment of the microgaps in mandibular first molar 2 post placement using stereomicroscopy.

4. Conclusion

In conclusion, the integration of digital workflows in implant dentistry marks a significant advancement in clinical practice, enhancing precision, efficiency, and predictability in treatment outcomes. The utilization of advanced technologies such as CBCT and intraoral scanning facilitates comprehensive treatment planning and the design of custom surgical guides, ultimately leading to more accurate implant placements and improved patient satisfaction. The evidence supporting the benefits of both static and dynamic navigation techniques underscores their essential roles in optimizing implant placement and prosthetic outcomes.

Moreover, while discrepancies in acceptable marginal fit levels remain a topic of debate, the transition towards 3D analysis presents a promising avenue for more accurate assessments, potentially enhancing the validity of future studies. As the field continues to evolve, embracing these digital innovations not only streamlines clinical workflows but also reinforces the importance of effective communication with patients. Overall, the findings of this research advocate for the continued exploration and implementation of digital technologies in implant dentistry to achieve superior clinical outcomes and elevate patient care.

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