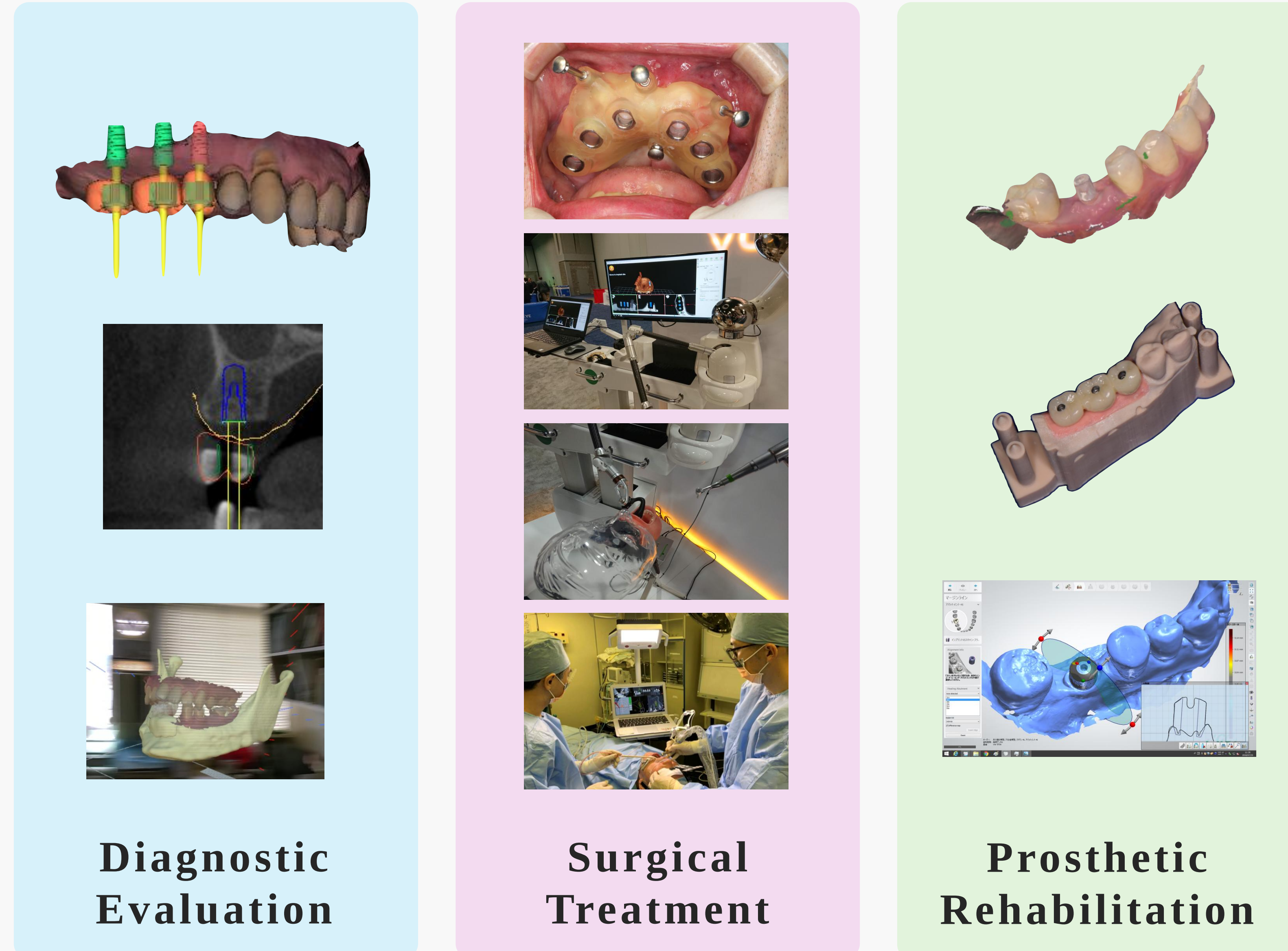


Introduction



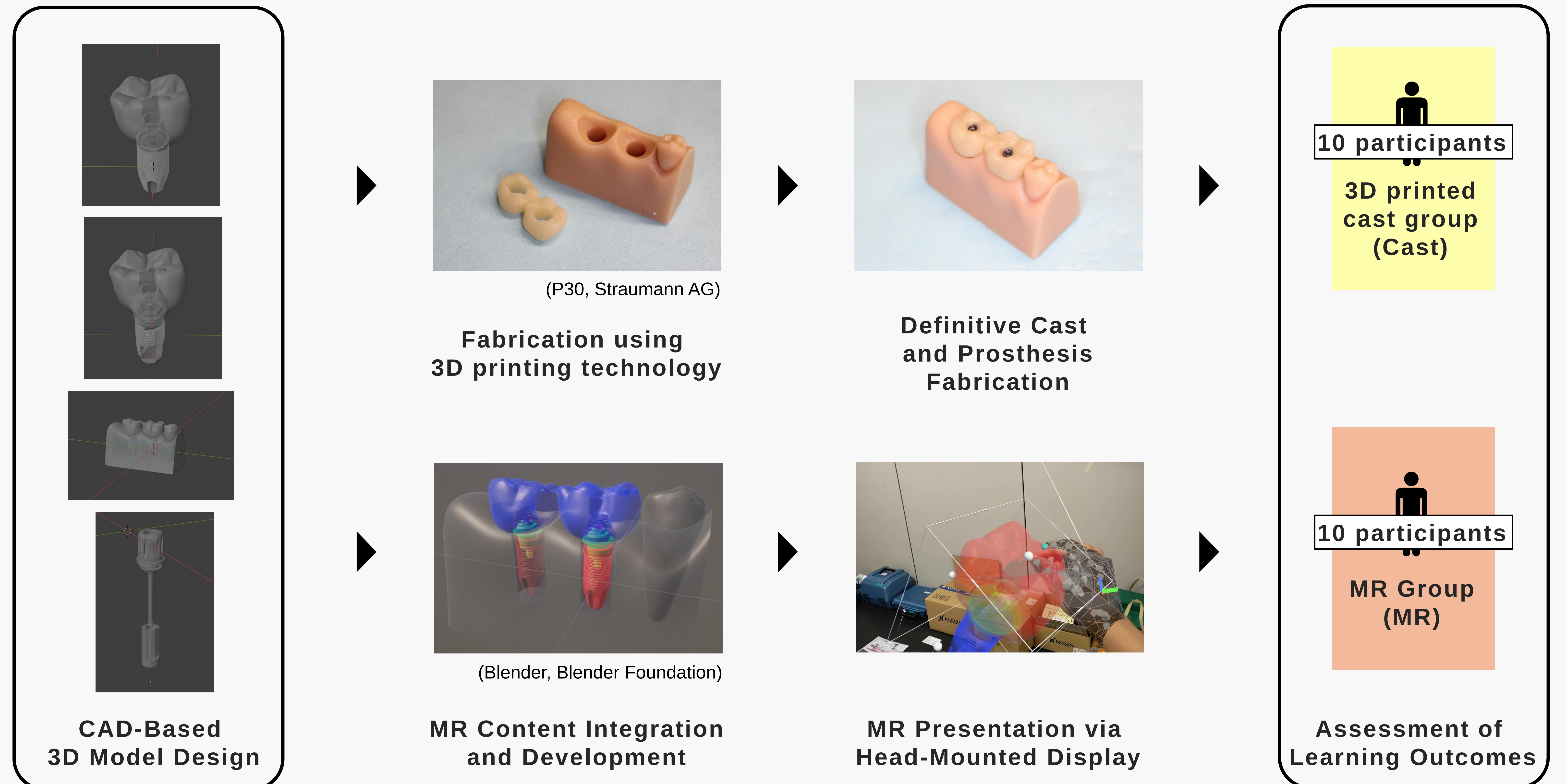
Digital technology enhances diagnosis, surgical procedures, and prosthetic rehabilitation in oral implantology ; however, its application in dental education remains underutilized. Understanding implant structure is essential for successful implant treatment, and Mixed Reality (MR), a form of Extended Reality (XR), offers immersive 3D visualization that has been widely implemented in industrial education. Nevertheless, its effectiveness in enhancing dental students' comprehension of implant structure remains underexplored. Further research is required to evaluate its educational impact.

Aim of the study

This study evaluates the effectiveness of MR combined with a conventional cast in enhancing dental students' understanding of implant structure by comparing their comprehension before and after MR-based training.

Materials and methods

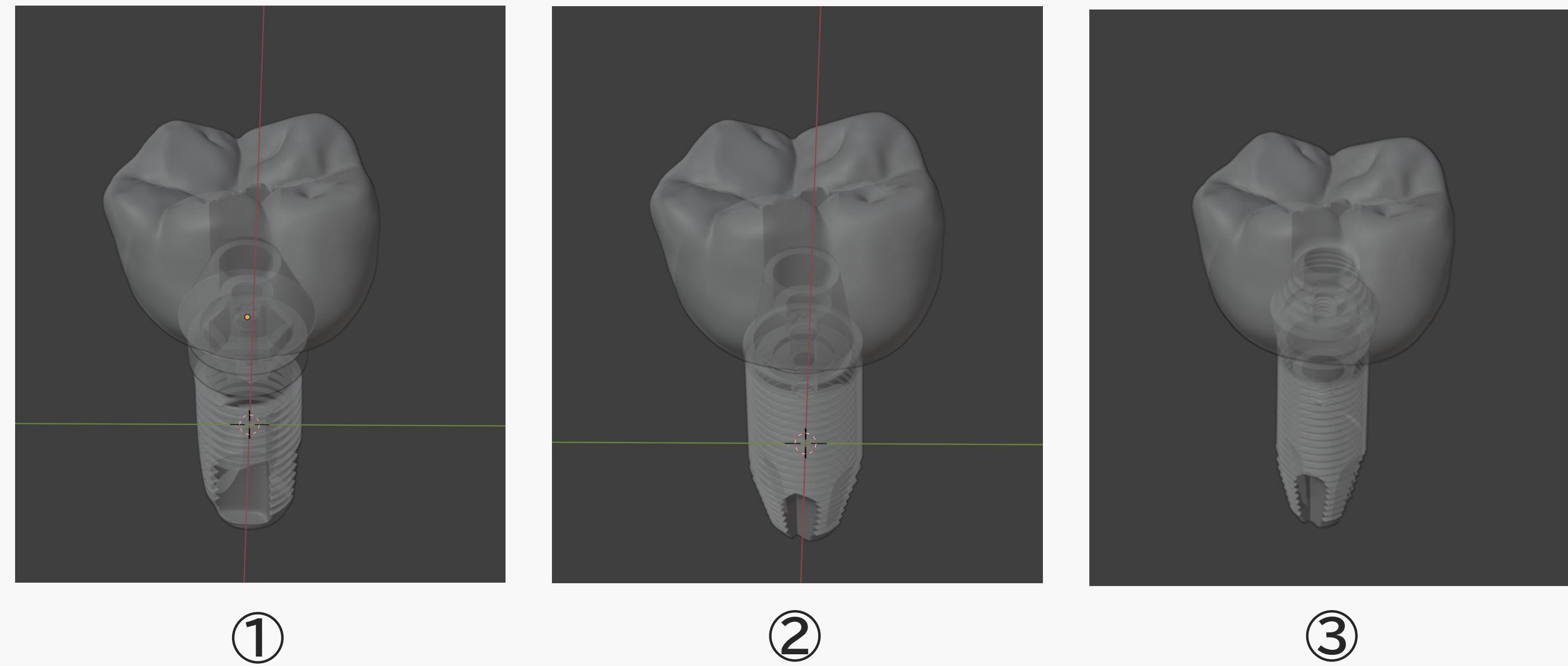
- A 3D model was created and used to develop a Mixed Reality (MR) application, implemented in a head-mounted display.
- The application was utilized to teach implant structure to dental students.



- Participants: 20 fifth-year dental students, divided into:
 - **Cast group (n=10):** Explained using physical models.
 - **MR group (n=10):** Explained using the MR application.
- The understanding of implant structure was compared between the two groups.

Materials and methods

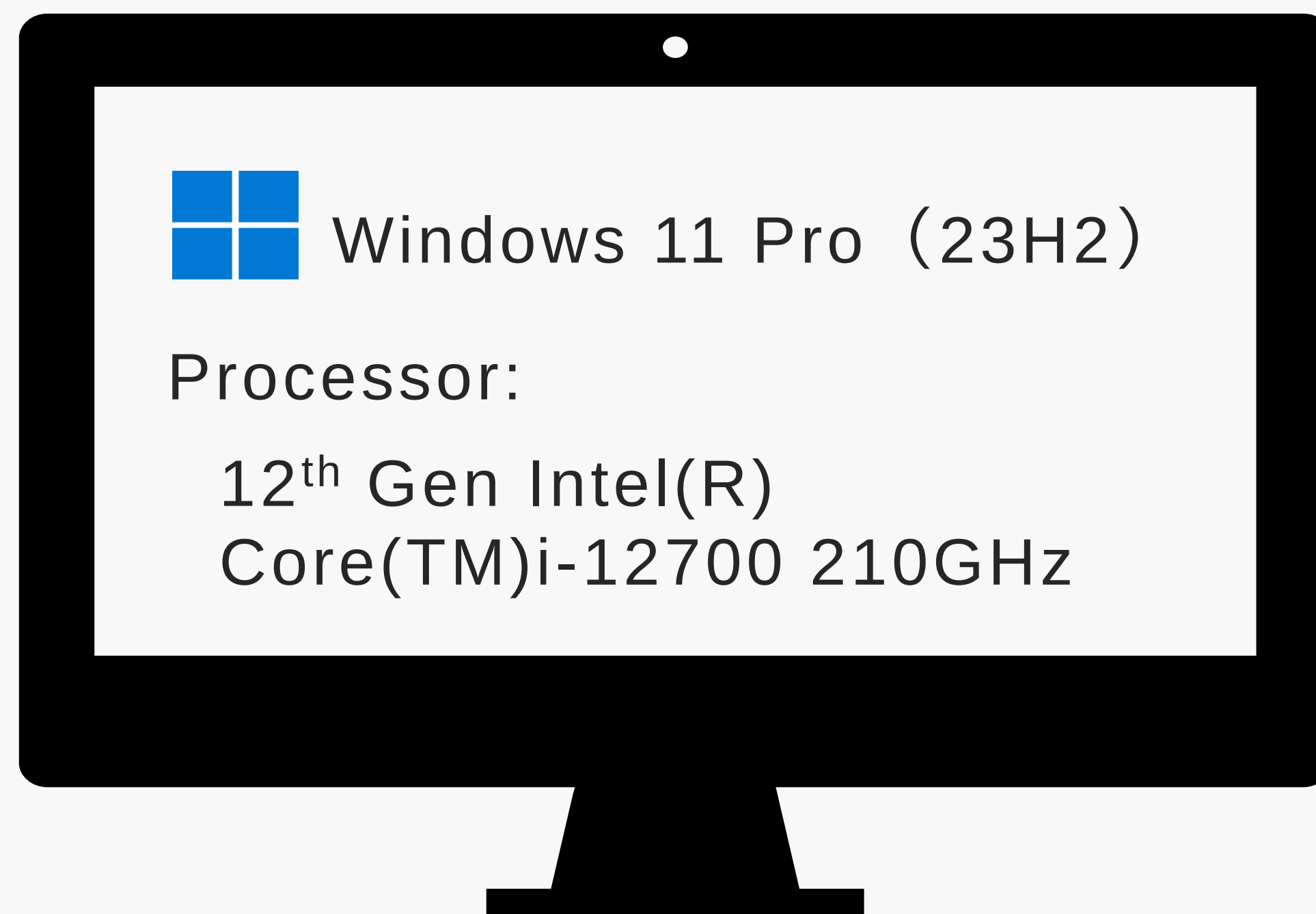
I 3D Model Creation



3D Modeling of Implant Connection Types

- **Software:** General-purpose CAD software (Blender, Blender Foundation).
- **Design:**
 - ① External implant.
 - ② Internal implant.
 - ③ Internal implant with screw-retained abutment.
- **Components:** Implant body, superstructure, fixation screws.
- **Export format:** FBX.

II MR Application Development

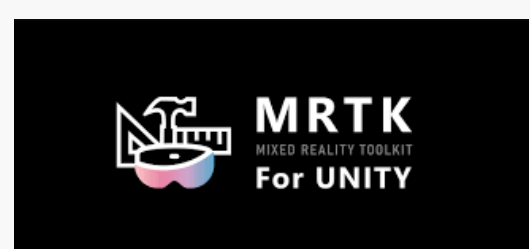


Unity (2022.3.37f1)

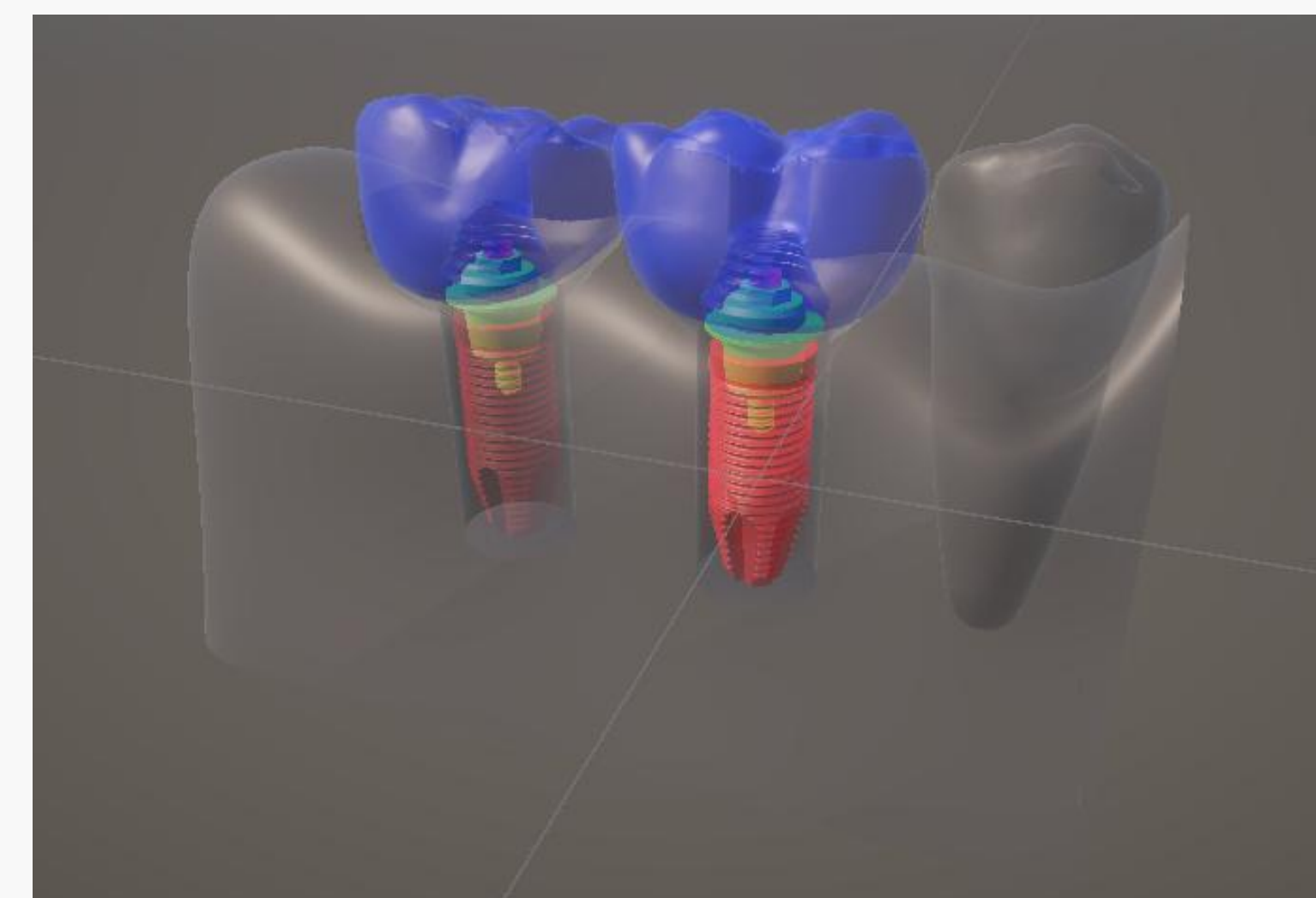
Programming Language : C#



Visual studio 2022



Mixed Reality Toolkit for Unity 3.0



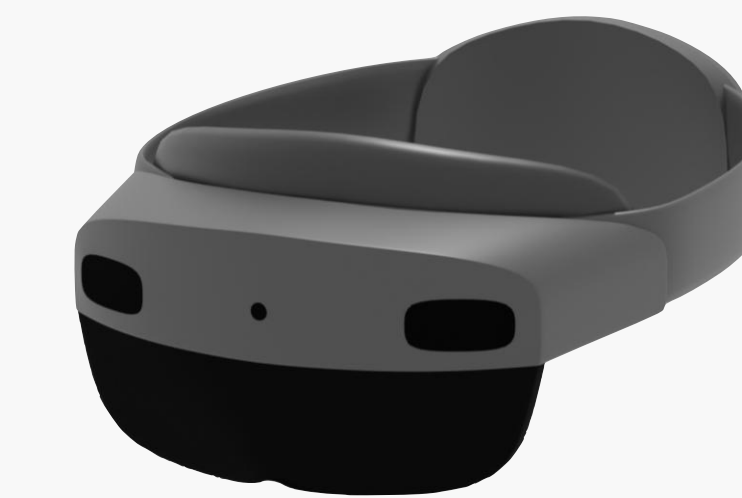
Button-Based Interactive Control

- **Resize:** Adjust object size.
- **Rotate:** Rotate the object.
- **Translate:** Move the object linearly.
- **Move:** Separate individual components.
- **Reset:** Restore to the original state.



A code-assisted approach was used to develop the script.

III Application Operation



(HoloLens 2, Microsoft)

The operation procedure was verified with other students via Miracast prior to the experiment. All implant-related explanations were provided by a board-certified specialist from the Japan Society of Oral Implantology.

IV Survey Questionnaire

A Google Forms survey was administered for two groups:

1. Cast group
2. MR group

The survey links were generated as QR codes to allow anonymous smartphone responses after the experiment.

Pre-experiment survey

Survey was conducted using both 3D-printed models and MR

Post-experiment survey

1. **Understanding** of the differences among external, internal, and internal with screw-retained abutments connections in oral implantology.
2. **Helpfulness** of this learning method in understanding implant connection differences.
3. Level of **interest** in this learning method.
4. **Clarity** of explanations in this learning method.
5. Ease of **use** of this learning method.
6. Element of **surprise** in this learning method.
7. Level of **discomfort** experienced with this learning method.

*Participants were asked to rate the following items on a 5-point scale.

Surveys for the Cast and MR groups were administered via QR codes using Google Forms. Participants responded anonymously before and after the experiment, rating seven items on a 5-point Likert scale. The results were subjected to statistical analysis.

Materials and methods

V Practical application

i Cast group



Three types of casts were used to explain the structure of implants.

ii MR group



Windows and HoloLens 2 were integrated to enhance instructors' ability to guide students more effectively.



QR code attached for a video demonstrating HoloLens 2 operation.

Results

No.	Questions	Pre-experiment survey	Post-experiment survey		P
			Cast group (Mean ± Standard Deviation)	MR group (Mean ± Standard Deviation)	
1	Understanding	1.8 ± 0.836	3.6 ± 1.140	4.8 ± 0.447	<0.05*
2	Effectiveness in Understanding		4.0 ± 1.224	4.8 ± 0.447	
3	Interest		3.8 ± 1.303	4.8 ± 0.447	<0.05**
4	Clarity		3.8 ± 1.095	5	<0.05**
5	Ease of Use		4.2 ± 1.303	2.4 ± 0.894	
6	Element of Surprise		1.4 ± 0.547	4.8 ± 0.447	<0.05**
7	Discomfort		1.2 ± 0.447	2.0 ± 1.732	

*: Wilcoxon Signed-Rank Test **: Mann-Whitney U-test

- **Understanding** : Both Cast and MR groups showed significant improvement after the experiment, with the MR group scoring significantly higher than the Cast group.
- **Effectiveness in Understanding**: No significant difference between MR and Cast groups.
- **Interest & Clarity**: The MR group scored significantly higher.
- **Ease of Use**: No significant difference between the MR and Cast groups.
- **Element of Surprise**: The MR group scored significantly higher.
- **Discomfort**: No significant difference between the MR and Cast groups.

Discussion

Undergraduate education in oral implantology varies significantly, leading to inconsistencies in training quality. Mixed Reality technology can supplement missing content by providing a structured, flexible, and interactive learning environment. This approach enhances student engagement, increase interest in oral implantology, and improves educational outcomes.

Conclusion

- **Mixed Reality** is effective for teaching **both general anatomy and implant connection structures**.
- MR technology **enhances students’ understanding** of implant connection structures.
- Future studies will investigate **the integration with hands-on training** to further enhance **surgical training and clinical applications**.

