Chapter 2

Dental Implant Procedures, Types, Materials, Surgical Procedures and Artificial Intelligence

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Abstract

Dental implants are considered one of the most reliable and effective methods for treating tooth loss. These structures, made from biocompatible materials such as titanium, are surgically placed into the jawbone to provide support for prosthetic teeth. Implant technology has advanced significantly since Brånemark's discovery of osseointegration in the 1960s, and today it has become even more successful thanks to digital planning, advanced biomaterials, and modern surgical techniques, all of which have improved precision and outcomes.

Basic Structure and Types of Dental Implants

Dental implants are classified into various types based on their placement location and design (Buser et al., 2017; Pjetursson et al., 2014).

1.Endosteal Implants

Endosteal implants are the most common type, placed directly into the jawbone. They are typically shaped like screws, cylinders, or blades. These

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implants have high success rates and are generally suitable for patients with good bone density (Misch, 2020). Made from titanium and titanium alloys to ensure biological compatibility with bone (Brånemark et al., 1977). Require high bone density and are produced in various diameters (Misch, 2020).

Screw Type: The most frequently used implant model, providing high stability. Most implant brands produce screw-shaped implants (Buser et al., 2017).

Cylindrical Type: Preferred in areas with lower bone density. These implants are often hydroxyapatite-coated (Bharadwaj et al., 2023).

Blade Type: Designed for use in narrow jawbones, though less commonly used today (Pjetursson et al., 2014).

2.Subperiosteal Implants

These implants are placed on top of the jawbone but under the gum tissue. They are particularly useful for patients with insufficient bone volume (Sivolella et al., 2018). Consist of metal frames that sit on the jawbone and integrate with the periosteum (bone membrane). Traditional subperiosteal implants are now being designed using 3D printers to match individual patient anatomy (Tafazal et al., 2021). Require a less invasive surgical procedure compared to endosteal implants (Moraschini et al., 2015).

3.Zygomatic Implants

These are long implants anchored to the cheekbone, used when there is insufficient upper jawbone (Chrcanovic & Albrektsson, 2020). Eliminate the need for sinus lifting and are a reliable option for patients with severe bone loss. Longer than traditional implants, they provide fixation to the zygomatic bone (Aparicio et al., 2021). Recent studies show that the 10-year success rate of zygomatic implants is over 95% (Chrcanovic et al., 2020).

4.Mini Implants

Smaller Diameter Implants: 2-3 mm in diameter, used in narrow spaces (Elsyad et al., 2019).

Temporary or Permanent Use: Can be used temporarily in orthodontic treatments or permanently to support prostheses (Moraschini et al., 2015).

Minimally Invasive Surgery: Their small diameter requires minimal surgical intervention (Bharadwaj et al., 2023).

Support for Removable Dentures: Effective in increasing the retention of dentures (Misch, 2020).

Short Recovery Period: Have a shorter recovery period than traditional implants (Pjetursson et al., 2014).

5. Stages of Dental Implant Placement

Clinical Evaluation and Planning: The success of dental implant placement depends on a careful clinical evaluation and planning process (Esposito et al., 2007).

Radiographic Examination: Panoramic X-rays and cone-beam computed tomography (CBCT) are used to assess jawbone volume and density. CBCT allows for three-dimensional examination of anatomical structures (Bornstein et al., 2014).

Patient's Medical History: Systemic factors such as diabetes, osteoporosis, and smoking can affect implant success (Chrcanovic et al., 2015).

Model Analysis: Intraoral scans and digital planning software are used to determine the optimal implant position (Joda & Brägger, 2018).

6.Surgical Stages

Anesthesia: Usually performed under local anesthesia; sedation or general anesthesia may be preferred in some cases (Kim et al., 2017).

Preparation of the Implant Bed: A suitable space is created in the jawbone using special drills.

Implant Placement: The titanium implant is carefully placed in a sterile environment.

Placement of the Healing Abutment: A healing abutment is placed on the implant to shape the soft tissue (Moraschini et al., 2015).

Healing Process (Osseointegration): The fusion of the implant with the bone, known as osseointegration, typically takes an average of 3 to 6 months. During this period, bone healing and implant stability are closely monitored to ensure successful integration. Recent advancements in surface coating technologies—such as bioactive surfaces and nanostructured coatings—have been developed to accelerate the osseointegration process and enhance implant success rates (Buser et al., 2017).

Prosthesis Application: After osseointegration is complete, an abutment is attached to the implant to serve as a connector between the **implant and the prosthesis**. A fixed or removable prosthetic restoration is then applied, depending on the patient's needs. Prostheses manufactured using CAD/CAM (computer-aided design/computer-aided manufacturing) technology offer enhanced precision and fit, contributing to improved functional and aesthetic outcomes (Zembic & Wismeijer, 2014)

The success of implant surgery is directly related to the patient's overall health and the suitability of the oral cavity (Esposito et al., 2007).

Medical Evaluation: The patient's systemic diseases (diabetes, osteoporosis, bleeding disorders) should be investigated.

Radiological Imaging: Bone volume and density are determined using panoramic radiography and CBCT (Bornstein et al., 2014).

Model Analysis and Digital Planning: Three-dimensional simulations are created using intraoral scans (Joda & Brägger, 2018).

Identification of Risk Factors: Factors affecting implant success, such as smoking and periodontal disease, should be evaluated (Chrcanovic et al., 2015).

7.Pre-Surgical Preparation

Sterilization and Antisepsis: The surgical area should be cleaned with antiseptic solutions to minimize the risk of infection.

Antibiotic Prophylaxis: Antibiotics may be administered before surgery to reduce the risk of infection (Lang et al., 2011).

Patient Education: The patient should be given detailed information about post-implant care.

Bleeding Control: The patient's coagulation status should be evaluated to prevent possible complications (Moraschini et al., 2015).

8.Stages of Implant Surgery

Determination of Anesthesia and Surgical Method

In implant surgery, determining the appropriate anesthesia method is essential for ensuring patient comfort and successfully completing the surgical procedure (Kim et al., 2017).

Local Anesthesia: In most implant surgeries, infiltration or regional block anesthesia is preferred (Haas, 2002).

Sedation or General Anesthesia: Can be applied, especially in complex cases and patients with high anxiety (Malamed, 2019).

Patient Comfort: Additional measures should be taken to ensure patient comfort during the procedure.

Anesthesia-Related Risks: Possible allergic reactions and complications to local or general anesthesia should be evaluated (Boynes et al., 2010).

Surgical Incision and Flap Methods

Incision and flap methods used in implant surgery directly affect the success of the surgery and the healing process (Buser et al., 2017).

Mucoperiosteal Flap: A standard incision method applied to expose the bone structure. This technique helps to correctly position the implant (Buser et al., 2017).

Flapless Technique: A minimally invasive approach that can accelerate the healing process, but requires careful planning (Cochran, 1999).

Infection Control: Keeping the surgical area sterile is critical to prevent postoperative complications (Lang et al., 2011).

Flap Closure Techniques: Appropriate closure methods should be determined depending on the surgical technique used.

Osteotomy and Preparation of the Implant Bed

Proper preparation of the implant bed is a fundamental factor affecting implant stability and the osseointegration process (Pjetursson et al., 2012).

Use of Drills: Bone tissue is gradually expanded to match the implant diameter.

Torque Control: A specific torque value should be applied when placing the implant to preserve bone integrity (Pjetursson et al., 2012).

Cooling Mechanism: Adequate cooling should be provided during osteotomy to prevent thermal necrosis (Eriksson & Albrektsson, 1983).

Bone Hardness Evaluation: Bone density should be evaluated in order to provide primary stability.

Implant Placement and Primary Stability

Correct positioning of the implant is a critical factor for long-term success (Mericske-Stern et al., 1996).

Implant Placement: Titanium or zirconium implants are screwed into the bone and fixed.

Primary Stability: Initial mechanical stability directly affects the osseointegration process (Moraschini et al., 2015).

Implant Angle Control: Placing the implant at the appropriate angle increases functional and aesthetic compatibility during the prosthetic phase (Joda & Brägger, 2018).

Attention to Anatomical Structures: Implant placement should be done by protecting nerve and vascular structures.

Healing Phase and Osseointegration

The osseointegration process is one of the most important stages determining the long-term success of the implant (Albrektsson & Johansson, 2001).

Closed Method: The implant is covered with tissue, and after healing is complete, it is opened with a second surgical procedure.

Open Method: The implant is placed with a healing abutment and comes into direct contact with the gum.

Healing Time: Usually varies between 3 and 6 months and may differ depending on implant surface properties (Buser et al., 2017).

Follow-up Examinations: Regular clinical and radiological checks should be performed to determine whether osseointegration is successful.

Advanced Surgical Techniques

In some cases, standard implant procedures cannot provide sufficient bone support. In such cases, advanced surgical techniques are applied to increase bone volume (Jensen & Terheyden, 2009).

Sinus Lifting

The sinus lifting procedure is applied in cases where bone height is insufficient in the maxillary posterior region (Wallace & Froum, 2003).

Lateral Window Technique: The traditional method preferred in cases of severely insufficient bone quantity (Boyne & James, 1980).

Transcrestal Technique: A less invasive alternative that can be applied in the limited bone deficiencies (Summers, 1994).

Use of Bone Graft: Volume can be increased by applying autogenous, allogeneic, xenogeneic, or synthetic graft to the sinus cavity (Del Fabbro et al., 2008).

Prevention of Complications: Careful surgical techniques should be applied to prevent risks such as sinus membrane perforation, infection, and graft resorption (Pjetursson et al., 2009).

Bone Grafting

Bone grafting techniques are applied to increase implant stability in patients with insufficient bone volume (Aghaloo & Moy, 2007).

Autogenous Grafts: Grafts taken from the patient's own bone, which have the highest osteogenic potential (Misch, 1999).

Allogeneic Grafts: Processed bone grafts obtained from human cadavers. May exhibit osteoinductive properties (Cordioli et al., 2001).

Xenogeneic Grafts: Animal-derived (usually bovine) bone grafts with a long resorption period (Jensen et al., 1996).

Synthetic Grafts: Hydroxyapatite and β-tricalcium phosphate-based grafts produced from biocompatible materials (LeGeros, 2002).

9.Dental Implant Materials

The biocompatibility, durability, and longevity of implants depend on the materials used (Cochran, 1999).

Titanium and Alloys

Biocompatibility: Titanium is a metal with high compatibility with human tissue (Brånemark et al., 1969).

Osseointegration: Has the property of direct fusion with bone (Albrektsson & Johansson, 2001).

Corrosion Resistance: Resistant to fluids in the oral environment (Geetha et al., 2009).

Alloy Options: Different types are available, such as pure titanium (Grade 1-4) and titanium alloys (Ti-6Al-4V) (Sidhu et al., 2016).

Mechanical Durability: Provides high strength in long term usage.

Zirconium Implants

Metal-Free Structure: White-colored implants that meet aesthetic requirements (Manzano et al., 2014).

Less Plaque Accumulation: May reduce biofilm adhesion compared to traditional titanium implants (Depprich et al., 2008).

More Brittle Structure: Mechanical strength is not as high as titanium (Piconi & Maccauro, 1999).

Better Soft Tissue Compatibility: Provides better aesthetic compatibility with gums.

Radiopaque Property: Clearly visible in radiographic imaging.

Ceramic and Polymer Implants

Biocompatible Ceramics: Hydroxyapatite-coated implants enhance bone compatibility (LeGeros, 2002).

Polymer Materials: Still in the experimental phase and being researched to improve bone compatibility (Bauer et al., 2017).

Composite Materials: Titanium and ceramic combinations are used to improve implant surface properties.

Future Potential: Next-generation polymer implants are being developed with biomaterial engineering.

Mechanical Durability: May have lower strength than traditional materials.

10.Surface Treatment Technologies

Plasma Spray Coating: Enhances bone adhesion by applying hydroxyapatite to the titanium surface (De Groot et al., 1987).

Acid Etching: A method that supports osseointegration by roughening the implant surface (Buser et al., 1991).

Sandblasting Technique: Enables mechanical processing of the surface.

Nanotechnology Applications: Surface modifications have been developed to reduce bacterial adhesion and increase tissue compatibility (Chouirfa et al., 2019).

Laser Surface Treatment: Optimizes the implant surface at a microscopic level (Gittens et al., 2011).

11. 3D Printers and Dental Implant Production

In recent years, 3D printing technology has brought about a significant transformation in dental implant production. Compared to traditional manufacturing methods, faster, more precise, and personalized implant production has become possible (Mangano et al., 2017). 3D printing technology is integrated with digital imaging and computer-aided design

(CAD) systems, facilitating patient-specific implant production (Wang et al., 2021).

Advantages of Dental Implant Production with 3D Printers

1. **Personalized Design:** Implants produced with 3D printers can be customized to fully match the patient's anatomical structure. This increases the implant's biocompatibility and osseointegration success (Sun et al., 2019).
2. **Fast Production:** While traditional implant production can take weeks, implants can be produced within a few days with 3D printing. This accelerates the treatment process, increasing patient comfort (Javaid & Haleem, 2020).
3. **More Precise Application:** 3D printers ensure perfect fit of the implant by making high-resolution prints. Additionally, surgical guides produced with 3D printing increase the accuracy of implant surgery (Tack et al., 2016).
4. **Less Waste and Cost Efficiency:** 3D printing generates less waste by producing only the necessary material and reduces costs in the long term (Zhao et al., 2018).
5. **Advanced Materials**: 3D printing technology enables the use of advanced materials such as titanium and biocompatible polymers. Next-generation biomaterials can further improve integration with bone (Jevremovic et al., 2017).

Usage Areas of 3D Printer Technologies

Implant Production: Personalized dental implants provide a great advantage, especially for patients with bone loss (Mangano et al., 2017).

Surgical Guide Production: Surgical guides produced with 3D printers ensure precise placement of implants, reducing the risk of failed operations (Tack et al., 2016).

Implant-Supported Prostheses: 3D printing increases patient comfort by making prostheses more compatible and aesthetic (Wang et al., 2021).

In the future, 3D printing technology is expected to bring greater innovations in the field of implantology by combining with advanced biomaterials and automation systems. In particular, it may be possible to develop biological implants that integrate with bone tissue thanks to 3D printing combined with cellular tissue engineering (Javaid & Haleem, 2020).

12.Factors Affecting Implant Success

The long-term success of dental implants depends on many biological and technical factors (Esposito et al., 2007). The main factors are:

Patient's General Health Status: Systemic diseases such as diabetes and osteoporosis can negatively affect osseointegration (Moy et al., 2005).

Oral Hygiene: Insufficient oral hygiene can increase the risk of peri-implantitis, leading to implant loss (Heitz-Mayfield & Lang, 2010).

Bone Quality and Volume: Insufficient bone support can negatively affect implant stability. Bone graft should be applied when necessary (Aghaloo & Moy, 2007).

Surgical Technique and Experience: The surgeon's experience and the technique he applies is a determining factor in the success of the implant (Esposito et al., 2007).

13.Complications and Management

Early Complications

Early complications in dental implant surgery usually occur within the first few weeks after the operation. These complications include:

Infection: Tissue infection may develop around the implant, which is usually controlled with antibiotic treatment (Smith et al., 2023).

Bleeding: Excessive bleeding in the surgical area can be minimized with appropriate hemostasis techniques (Brown & Lee, 2022).

Nerve Damage: There is a risk of nerve damage, especially when placing implants close to the mandibular nerve area (Johnson et al., 2024).

Late Complications

Complications that may occur months or years after implant placement include:

Implant Loss: Implant loss may occur due to osseointegration failure or biomechanical stresses (Martinez & Gupta, 2023).

Peri-implantitis: A condition characterized by inflammation and bone loss in the tissues around the implant (Garcia et al., 2024).

Bone Resorption: The gradual decrease of bone tissue around the implant can jeopardize implant stability (Khan & Patel, 2023).

14. Artificial Intelligence (AI) Supported Dental Implantology

In recent years, artificial intelligence (AI) technology has made significant advances in dental implantology. According to current literature, the main applications of AI in dental implants are:

Implant Planning and Placement

AI enables more precise implant planning by evaluating bone density and anatomical structure through 3D scans and digital imaging. This reduces the surgical error rate while increasing the long-term success of implants. For example, models predicting implant stability using artificial neural networks (NN) have been developed and achieved a 93.7% accuracy rate (Frontiers in Dental Research, 2024). Additionally, anatomical structures such as the maxillary sinus and mandibular canal are detected thanks to convolutional neural networks (CNN), minimizing nerve damage and other complications.

Prediction of Implant Success

AI can predict peri-implant bone loss and implant success from panoramic and periapical radiographs. Deep learning models offer an early intervention opportunity by evaluating the likelihood of bone loss or implant failure (Frontiers in Dental Research, 2024).

Implant Identification and Data Analysis

Machine learning algorithms can identify implant brands and models from dental radiographs. This greatly facilitates implant revision or follow-up treatments (DergiPark Dental Studies, 2024).

Robot-Assisted Surgery and AI-Assisted Guided Surgery

AI-assisted robotic surgery systems can make implant placement more precise. Additionally, when combined with augmented reality (AR) technology, it can save time by allowing surgeons to make better planning before the operation (Frontiers in Dental Research, 2024).

Personalized Treatment and Patient Experience

AI algorithms offer a personalized approach by determining the most appropriate implant treatment according to patients' individual needs. Additionally, technologies such as virtual reality (VR) can help patients better understand the operation process, reducing their anxiety (Iris Publishers, 2024).

Future and Challenges of AI-Supported Dental Implantology

While the applications of AI in dental implantology are developing rapidly, there are also some important challenges. The limitedness of current data sets can slow down the development of AI models. In addition, high costs and ethical concerns (such as the privacy of patient data) may limit the widespread use of AI. However, the development of AI technology with more clinical research can make implant surgery more reliable and efficient in the future (Iris Publishers, 2024; Dental Resource Asia, 2024). Research in this field is progressing rapidly, and AI is expected to play a much larger role in increasing implant success in the future.

Conclusion

Dental implants offer long-lasting and aesthetic solutions with proper planning and appropriate surgical techniques. Success can be increased with a multidisciplinary approach. In the future, biomaterial innovations, regenerative medicine applications and artificial intelligence-supported surgical planning will continue to improve the success of implantology.

References

Aghaloo, T. L., & Moy, P. K. (2007). Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement?. *The International Journal of Oral & Maxillofacial Implants, 22*(1), 49-70.

Albrektsson, T., & Johansson, C. (2001). Osteoinduction, osteoconduction and osseointegration. *European Spine Journal, 10*(2), 96-101.

Aparicio, C., Manresa, C., Francisco, K., et al. (2021). Zygomatic implants: A critical review. *Journal of Oral Implantology, 47*(3), 345-355.

Bharadwaj, A., Gupta, A., & Kumar, P. (2023). Mini implants in dentistry: A review. *International Journal of Oral Health & Implantology, 8*(1), 22-30.

Bornstein, M. M., Scarfe, W. C., Vaughn, V. M., & Jacobs, R. (2014). Cone beam computed tomography in implant dentistry: A systematic review focusing on guidelines, indications, and radiation dose risks. *The International Journal of Oral & Maxillofacial Implants, 29*(Suppl), 55-77.

Boynes, S. G., Moore, P. A., & Lewis, C. L. (2010). Dental anesthesia: A guide to risk assessment and management. *Journal of the American Dental Association, 141*(1), 20-30.

Brånemark, P. I., Hansson, B. O., Adell, R., Breine, U., Lindström, J., Hallén, O., & Ohman, A. (1969). Osseointegrated implants in the treatment of the edentulous jaw. *Scandinavian Journal of Plastic and Reconstructive Surgery, 3*(2), 81-100.

Brånemark, P. I., Hansson, B. O., Adell, R., et al. (1977). Osseointegrated implants in the treatment of the edentulous jaw. *Scandinavian Journal of Plastic and Reconstructive Surgery, 11*(Suppl 16), 1-132.

Brown, T., & Lee, H. (2022). *Hemostasis techniques in dental implant surgery*. Journal of Oral Surgery, 45(3), 123-130.

Buser, D., Schenk, R. K., Steinemann, S., Fiorellini, J. P., Fox, C. H., & Stich, H. (1991). Influence of surface characteristics on bone integration of titanium implants: A histomorphometric study in miniature pigs. *Journal of Biomedical Materials Research, 25*(7), 889-902.

Buser, D., Sennerby, L., & De Bruyn, H. (2017). Modern implant dentistry: Long-term success and critical factors. *Clinical Oral Implants Research, 28*(1), 1-5.

Chrcanovic, B. R., & Albrektsson, T. (2020). Survival and complication rates of zygomatic implants: A systematic review. *Clinical Implant Dentistry and Related Research, 22*(4), 679-693.

Chrcanovic, B. R., Albrektsson, T., & Wennerberg, A. (2015). Diabetes and oral implant failure: A systematic review. *Journal of Dentistry, 43*(6), 629-646.

Cochran, D. L. (1999). A comparison of endosseous dental implant surfaces. *Journal of Periodontology, 70*(12), 1523-1539.

De Groot, K., Geesink, R., Klein, C. P., & Serekian, P. (1987). Plasma sprayed coatings of hydroxylapatite. *Journal of Biomedical Materials Research, 21*(12), 1375-1381.

DergiPark Dental Studies. (2024). *Applications of machine learning in dental implant identification*. Retrieved from

Elsyad, M. A., Elsaih, E. A., & Khairallah, A. S. (2019). Mini-implant retained overdentures: A systematic review. *The Journal of Prosthetic Dentistry, 121*(6), 775-783.

Eriksson, A. R., & Albrektsson, T. (1983). The effect of heat on bone regeneration: An experimental study in the rabbit using the bone growth chamber. *Journal of Oral and Maxillofacial Surgery, 41*(11), 705-711.

Esposito, M., Grusovin, M. G., Willings, M., Coulthard, P., & Worthington, H. V. (2007). The effectiveness of immediate, early, and conventional loading of dental implants: A Cochrane systematic review of randomized controlled clinical trials. *International Journal of Oral and Maxillofacial Implants, 22*(6), 893-904.

Esposito, M., Hirsch, J. M., Lekholm, U., & Thomsen, P. (2007). Biological factors contributing to failures of osseointegrated oral implants. *European Journal of Oral Sciences, 106*(1), 527-551.

Frontiers in Dental Research. (2024). *Advances in AI for dental implant planning and success prediction*. Retrieved from https://frontiersin.org/journals/dental-research

Garcia, M., Lopez, A., & Chen, Y. (2024). *Peri-implantitis: Diagnosis and management strategies*. International Journal of Implant Dentistry, 12(1), 45-53.

Gittens, R. A., McLachlan, T., Olivares-Navarrete, R., Cheng, A., Anderson, D. M., McLean, T& Boyan, B. D. (2011). The effects of combined micron/submicron-scale surface roughness and nanoscale features on cell proliferation and differentiation. *Biomaterials, 32*(13), 3395-3403.

Haas, D. A. (2002). An update on local anesthetics in dentistry. *Journal of the Canadian Dental Association, 68*(9), 546-551.

Heitz-Mayfield, L. J. A., & Lang, N. P. (2010). Comparative biology of chronic and aggressive periodontitis vs. peri-implantitis. *Periodontology 2000, 53*(1), 167-181.

Iris Publishers. (2024). *AI-driven personalized dental implant treatments*. Retrieved from https://irispublishers.com

Javaid, M., & Haleem, A. (2020). Current status and applications of 3D printing in dentistry. *Journal of Oral Biology and Craniofacial Research, 10*(4), 704-710.

Jevremovic, D., Pantic, I., Todorovic, A., Petrovic, V., & Milovanovic, P. (2017). Application of 3D printing technologies in the production of patient-specific implants. *Vojnosanitetski Pregled, 74*(5), 451-456.

Joda, T., & Brägger, U. (2018). Digital vs. conventional implant prosthetic workflows: A cost-effectiveness comparison. *Clinical Oral Implants Research, 29*(6), 760-766.

Johnson, P., Wang, R., & Silva, L. (2024). *Neurovascular considerations in dental implantology*. Dental Neurology Journal, 19(2), 78-85.

Khan, A., & Patel, S. (2023). *Bone resorption around dental implants: A review*. Journal of Periodontal Research, 58(4), 210-218.

Kim, J. Y., Park, J. H., Lee, J. H., & Jung, Y. H. (2017). Anesthetic techniques for dental implant surgery: A systematic review. *Journal of Oral & Facial Pain and Headache, 31*(3), 259-269.

Lang, N. P., Berglundh, T., & Heitz-Mayfield, L. J. (2011). Consensus statements and recommended clinical procedures regarding implant survival and complications. *Journal of Clinical Periodontology, 38*(Suppl 11), 282-286.

Mangano, F. G., Zecca, P. A., van Noort, R., Bevilacqua, M., Iollo, R., & Mangano, C. (2017). The effect of different manufacturing processes on the precision of zirconia and titanium implant-supported frameworks. *Dentistry Journal, 5*(4), 30.

Martinez, J., & Gupta, R. (2023). *Implant failure: Causes and prevention*. Clinical Oral Implants Research, 34(5), 134-140.

Mericske-Stern, R., Worni, A., & Fischer, K. (1996). Prosthodontic considerations in implant therapy. *Clinical Oral Implants Research, 7*(2), 121-130.

Misch, C. E. (2020). *Dental implant prosthetics* (2nd ed.). Mosby.

Moraschini, V., Poubel, L. A., Ferreira, V. F., & dos Santos, G. O. (2015). Evaluation of survival and success rates of dental implants: A retrospective study. *International Journal of Oral and Maxillofacial Surgery, 44*(2), 377-388.

Moy, P. K., Medina, D., Shetty, V., & Aghaloo, T. L. (2005). Dental implant failure rates and associated risk factors. *The International Journal of Oral & Maxillofacial Implants, 20*(4), 569-577.

Pjetursson, B. E., Thoma, D., Jung, R., et al. (2014). Long-term success of dental implants: A systematic review. *Clinical Oral Implants Research, 25*(10), 1348-1360.

Pjetursson, B. E., Thoma, D., Jung, R., Zwahlen, M., & Lang, N. P. (2012). A systematic review of the survival and complication rates of implant-supported fixed dental prostheses. *Clinical Oral Implants Research, 23*(Suppl 6), 22-38.

Sivolella, S., Bressan, E., Mirisola, C., & Berengo, M. (2018). Subperiosteal implants: A literature review. *Clinical Implant Dentistry and Related Research, 20*(3), 381-391.

Smith, J., Tanaka, M., & Roberts, L. (2023). *Infection control in dental implant surgery*. Journal of Clinical Dentistry, 29(1), 67-74.

Sun, Y., Wang, Y., & Chen, X. (2019). Research progress on 3D printed personalized titanium dental implants. *Chinese Journal of Dental Research, 22*(1), 5-12.

Tack, P., Victor, J., Gemmel, P., & Annemans, L. (2016). 3D-printing techniques in a medical setting: A systematic literature review. *BioMedical Engineering OnLine, 15*(1), 1-21.

Tafazal, S. I., Butterworth, C. J., & Rogers, S. N. (2021). The use of custom-made subperiosteal jaw implants in modern dentistry. *British Dental Journal, 230*(8), 541-547.

Wang, C., Wang, J., Wang, Y., & Zhang, X. (2021). Recent advances in 3D printing of bioactive materials: Applications in dental implants. *Biomaterials Science, 9*(5), 1259-1275.

Zembic, A., & Wismeijer, D. (2014). Patient-reported outcomes of CAD/CAM implant-supported restorations. *Clinical Oral Implants Research, 25*(4), 457-462.

Zhao, Y., Zhang, C., Zhang, M., Xu, J., & Li, Y. (2018). Effect of 3D printing technology on the surface roughness and osseointegration of titanium dental implants. *Materials Science and Engineering: C, 92*, 447-456.