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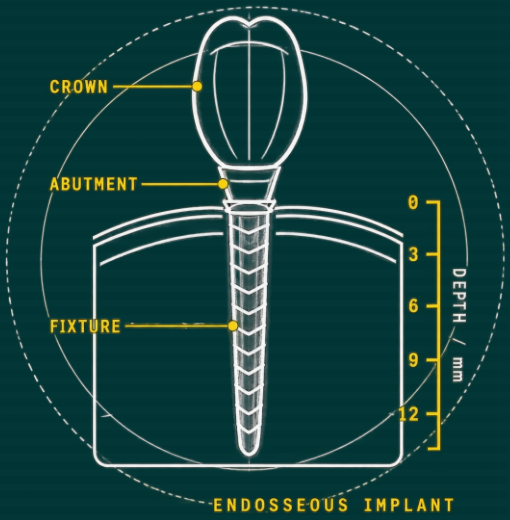
Maneuvers

in Basic Dental Implantology:

A STEP-BY-STEP CLINICAL GUIDE



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A Step-by-Step Clinical Guide

Font Fusions Publication

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patient care and clinical workflows. Authored by experts in the field, Advancements Across Oral Sphere serves as both a scholarly reference and a practical guide for professionals seeking to stay abreast of technological advancements in dentistry.

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Cephalometrics for Orthognathic Surgery: Principles, Planning, and Precision: This essential text unravels the science and clinical relevance of cephalometry in orthognathic surgery. From foundational anatomical landmarks to advanced radiographic analyses, “Cephalometrics for Orthognathic Surgery” provides a structured and insightful approach to diagnosing dento-facial deformities and planning treatment.

Clinical Decision - Making & Case Management in Physiotherapy: This book provides a comprehensive guide to understanding the principles of clinical decision-making and the case management process in physiotherapy. It covers essential topics such as clinical reasoning models, including hypothetico-deductive, pattern recognition, and narrative reasoning, and emphasizes the importance of evidence-based practice. Key steps in clinical decision-making, from subjective and objective assessments to goal-setting, treatment planning, and outcome evaluation, are thoroughly explained. The book also explores case management, highlighting the role of physiotherapists in coordinating care, working with multidisciplinary teams, and ensuring patient-centered care across different stages, from acute to chronic conditions. Ethical and legal considerations, including informed consent, confidentiality, and professional boundaries, are discussed to help practitioners navigate complex clinical and ethical situations. Real-world case scenarios provide practical insights into applying these concepts in musculoskeletal, neurological, and geriatric care

settings. Overall, the book serves as an invaluable resource for physiotherapists to enhance clinical decision-making and improve patient outcomes.

Evidence Based Dentistry: Dentistry is both an art and a science. This book explores the integration of scientific research and clinical expertise to provide the highest quality dental care. It defines evidence-based dentistry (EBD) as the judicious use of the best available clinical evidence combined with the dentist's experience and the patient's needs. The text covers the history and evolution of EBD, emphasizing its importance in the modern dental practice and the changing role of the patient in the decision-making process. From understanding the foundational principles to the step-by-step process of evidence-based learning, this book guides dental professionals through the process of applying evidence in clinical practice. It highlights the shift from tradition-based to evidence-based care, offering practical insights into improving clinical decision-making, enhancing patient care, and staying current with the latest research. A must-read for dental practitioners aiming to bridge the gap between scientific research and everyday clinical decisions.

The 10th Dentist: Innovations Transforming Modern Oral Care: This book offers a comprehensive and forward-looking account of the technological transformation reshaping contemporary dentistry, examining advances such as artificial intelligence, robotic and AI-guided surgery, regenerative medicine, tissue engineering, smart biomaterials, and 3D printing, and considering how each is redefining diagnostics, treatment planning, surgical precision, and patient outcomes. Across its chapters, the volume moves through imaging in oral cancer detection, clear-aligner orthodontics, periodontal regeneration, personalized prosthodontics, advanced regenerative strategies and material science, and the oral health needs of underserved populations, combining scientific depth with practical clinical relevance. Written in an accessible yet detailed style, and thoughtful in its treatment of the ethical questions and future challenges these innovations raise, *The 10th Dentist* serves as a valuable reference for dental professionals seeking to stay abreast of emerging trends and for readers with a broader interest in the future of oral healthcare.

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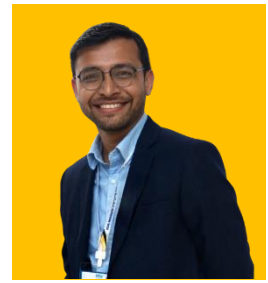
FOREWORD



Dental implantology has, within a single generation, moved from the margins of clinical practice to its centre. What was once the province of a few specialists is now an expectation of everyday patient care, and the replacement of missing teeth with osseointegrated implants has become one of the most predictable and rewarding treatments modern dentistry can offer. Yet the very success of the discipline has created a new challenge: the growing distance between the confidence with which implants are marketed and the depth of understanding with which they should be placed.

This book addresses that gap with admirable directness. Rather than overwhelming the reader with exhaustive theory, it returns to the fundamental maneuvers — the small, deliberate, repeatable acts of judgement and technique upon which every successful implant depends. From patient assessment and treatment planning, through the surgical placement of the fixture and the management of hard and soft tissue, to the prosthetic phase and the long years of maintenance that follow, the text follows the natural arc of treatment as it unfolds in the clinic. Each step is explained in the order it is performed, and the reasoning behind each decision is made plain.

The editors and contributing authors have drawn on wide clinical and academic experience to produce a guide that is at once rigorous and accessible. Students encountering implantology for the first time will find a clear and orderly path through a subject that can seem daunting; established practitioners will find a valuable reaffirmation of sound principle. It is a pleasure to commend this work to every clinician who wishes to place implants not merely competently, but well.

Dr. PRATIK BUMB
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Consultant Prosthodontist
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PREFACE

Implant dentistry is learned, above all, by doing — but doing well requires a clear map of what is to be done, in what order, and why. This book was conceived as exactly that map for the clinician who is beginning the journey into implantology, and as a dependable reference for those already on the way. Its purpose is not to catalogue every technique or every controversy in the field, but to set out the essential maneuvers of basic implant practice in a clear, step-by-step form that mirrors the sequence of actual treatment.

The chapters are arranged to follow a patient from the first consultation to lifelong follow-up. The book opens with a reflection on sustainable, responsible practice and then moves through patient assessment and treatment planning, the basic surgical maneuvers of implant placement, the management of soft and hard tissue, the healing and prosthetic phases, and finally the recognition and management of peri-implant disease and mechanical complications together with the maintenance that safeguards long-term success. In every chapter the emphasis falls on sound biological principle and careful, atraumatic technique, because these — far more than any single instrument or product — determine whether an implant succeeds.

This work is the fruit of collaboration among clinicians and academics from across the country, each contributing from a distinct field of expertise. I am grateful to the editors for their vision and diligence, to the contributing authors for the care they have taken with their chapters, and to the publisher for making this knowledge freely and widely available. It is my sincere hope that the reader will find in these pages a trustworthy companion at the chairside, and that the patients they treat will be the ultimate beneficiaries of the craft set down here.

Dr. Pratik Bumb

ACKNOWLEDGMENT

A book of this nature is never the work of a few hands alone, and it is a privilege to record our gratitude to all who made it possible.

Our first thanks go to the contributing authors, whose clinical wisdom and willingness to share it form the substance of every chapter. Their generosity with time and knowledge, in the midst of demanding professional lives, is the reason this guide exists. We are equally indebted to our teachers and mentors, whose example shaped our understanding of implant dentistry, and to our colleagues and students, whose questions continually sharpen it.

We gratefully acknowledge Font Fusions Publication in particular, for their commitment to open-access scholarship and for the professionalism with which they brought this book to print. Their belief in making sound clinical knowledge freely available has given this work a reach it could not otherwise have had.

Finally, we thank our families for their patience and unfailing support throughout the preparation of this book. Whatever is of value in these pages we owe in large part to them; the shortcomings that remain are our own.

Declaration: The authors used ChatGPT (OpenAI) solely for the generation of illustrative images included in this book.

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CHAPTER 1

SUSTAINABLE PROSTHODONTICS IN DENTISTRY: A NARRATIVE REVIEW

INTRODUCTION

Environmental sustainability is a global mandate that is increasingly being faced by all healthcare sectors, including dentistry. The dental profession produces a great amount of clinical and laboratory waste, uses large amounts of energy and relies on a wide range of complex, chemically produced substances which have a significant ecological impact when manufactured and disposed. The environmental impact of prosthodontics is an important contribution that we make with the regular use of impression materials, gypsum products, metallic alloys, acrylic resins, and ceramic systems. Sustainable dentistry, in general, involves the use of practices, materials and systems that are appropriate for the present day without hindering the ability of the next generation to do so [1]. In the realm of prosthodontics, this can be related to the selection of materials, minimizing waste, using digital technologies, energy efficiency and more importantly, the longevity of the restoration for the patient. Traditional prosthodontic procedures are dominated by non-reusable and/or non-biodegradable consumables. Certain polymeric impression materials, such as polyvinyl siloxane and polyether impression materials, are known to be persistent in landfill and cause particular problems of disposal [2]. Gypsum based die materials are used in large quantities worldwide and cause particular problems of disposal due to alkaline leachate contamination of groundwater [3]. With all these hurdles, however, a number of advances in the last decade have provided some promising avenues for the progression of prosthodontics toward sustainability. Each of these strategies can significantly decrease the environmental impact of prosthetic care: digital impression systems, computer-aided design and manufacturing (CAD/CAM), additive manufacturing, bio-based polymers, and enhanced alloy recycling facilities [4,5]. However, there is currently no review available that brings together the aspects of material science, digital technology, waste management and clinical implications in the context of sustainable prosthodontics [6]. This narrative review attempts to fill this void by reviewing what is currently known, identifying challenges and making recommendations for implementing sustainability into prosthodontic practice.

REVIEW

Environmental Burden of Conventional Prosthodontic Practice

There are a variety of environmental impacts associated with the use of traditional prosthodontic treatment. On the material side, making the cobalt-chromium and nickel-chromium alloys requires high energy consumption through smelting operations and results in particulate emissions and slag. Chemically stable silicone impression materials do not biodegrade, but are estimated to be several thousand tons of dental waste in high-income countries annually [7].

Another important source of residual monomer (methyl methacrylate, MMA) emission into clinical and laboratory environments is PMMA-based denture bases and provisional restorations, whereas the other one is dental gypsum in prosthodontic diagnostic casts and working models, which has an alkaline property and, if not disposed properly, is a source for groundwater contamination [8,9].

Another concern is the energy use in making the prosthetics. Porcelain-fused-to-metal (PFM) crowns require numerous kiln firings where the temperatures reach over 900°C while the traditional lost-wax casting process uses burnout furnaces and casting machines and increases the carbon footprint of the laboratory.

Sustainable Biomaterials in Prosthodontics

One of the most powerful approaches to minimize the environmental impact of prosthodontic care is material substitution. There has been increasing research investigating bio-based, recyclable and non-toxic alternatives to the traditionally used prosthetic materials [11].

Plant cellulose, polylactic acid (PLA) and polyhydroxyalkanoates (PHAs) have been studied as denture base materials. Their mechanical properties are still not as good as the properties of heat-cured PMMA in terms of flexural strength and water absorption resistance; however, improvements in composite reinforcement techniques, such as using nano-cellulose fillers, have started to close the performance gap [12].

In the fixed prosthodontics, high-translucency monolithic zirconia has become a metal-free restorative material that has been widely accepted in laboratory and clinical conditions [13]. But the zirconia processing requires sintering at high temperatures, and the service life and fracture resistance of the material can decrease the replacement frequency, which in turn can reduce the material cost of the service life [14].

Lithium disilicate glass-ceramics, such as used in making veneers and posterior restorations, lie somewhere in the middle: They're not as energy-consuming as metallic alloys, and they're compatible with the digital milling workflow, which cuts down on the amount of chemicals being used in the lab.

Table 1: Sustainable material options in prosthodontics

Material/Approach	Sustainability Benefit	Clinical Application	Limitation
Recycled PMMA	Reduced monomer waste	Denture bases	Limited strength data
Bio-based resins	Lower carbon footprint	Interim prostheses	Short clinical track record
Digital CAD/CAM	Minimizes material waste	Crowns, dentures, frameworks	High initial cost
3D-printed zirconia	Subtractive waste reduction	Fixed restorations	Post-sintering shrinkage

Table 1 summarizes current sustainable material options and their clinical applicability [15].

Waste Management and Pollution Control

The management of waste produced in prosthodontic practice is a combination of regulatory compliance and pro-active commitment of the clinician. Blood contaminated impression materials, tissue-conditioners, and expired chemicals are considered biomedical waste and should be segregated for disposal following national guidelines for biomedical waste management [15,16].

Although more applicable to restorative dentistry, amalgam separators are appropriate in any clinical practice where comprehensive prosthetic treatment is provided, because residual amalgam may be found in wastewater from the preparation of existing underlying restorations. The use of amalgam separator technology can remove more than 95% of particles prior to discharge and in several countries the use of amalgam separators is required in legislation [17].

Non-precious base metal alloys with cobalt and chromium are more difficult to recycle in the lab setting due to the lower market value and somewhat more specialized smelting requirements. However, it is better to use certified foundry-based recycling processes than landfill [18,19].

Elastomeric impression material waste that is produced in tremendous quantities in dental practices in general and particularly in prosthodontic practices is not currently recyclable in the existing dental waste management systems. The valorization of silicone wastes, such as re-using silicone as insulation or sealing material in industrial applications, is a new field of eco-circular design.

Table 2: Prosthodontic waste streams and green management strategies

Waste Stream	Volume Generated	Disposal Challenge	Green Alternative
Gypsum models	High	Landfill accumulation	Digital scanning
Impression materials	Moderate	Non-biodegradable	Digital impression
Metal alloy scraps	Low–moderate	Heavy metal leaching	Alloy recycling
Wax and investment	Moderate	Chemical contamination	Reusable alternatives

Table 2 outlines key prosthodontic waste streams and proposed management strategies.

Digital Dentistry and Sustainability

The shift towards digital workflows in prosthodontics may present the best opportunity to increase the sustainability of practices. In contrast, intraoral scanners completely eliminate the need for traditional impression materials, thus significantly reducing polymer waste in the clinical environment [20,21].

CAD/CAM milling from industrially manufactured ceramic or polymer blocks results in accurate restorations that don't require a lot of post fabrication adjustments, hence less remakes and material wastage. All-ceramic crowns fabricated by digital means had 35-45% less total material waste than PFM crowns fabricated by conventional casting [22].

Figure 1.1 summarizes this circular approach, linking material selection, digital fabrication, clinical use, repair/reline, and waste recycling into a continuous sustainability loop.

Photopolymerized resins and sintered ceramics can also be used for additive manufacturing, which offers a layer-by-layer alternative to traditional production processes, significantly increasing subtractive waste reduction. The sustainability of 3D printing in dentistry, however, is a complicated issue: The photopolymer resins used are chemically complex, and 3D printing waste disposal, if the material is not cured, creates environmental and occupational dangers [23].

The use of virtual articulation and occlusal planning software saves on remounting and equilibration procedures and consequently saves materials and chairside time. AI-driven design platforms are starting to show promise and potential for predicting the best morphology of the restoration the first time, decreasing the need for iteration with material usage [24].

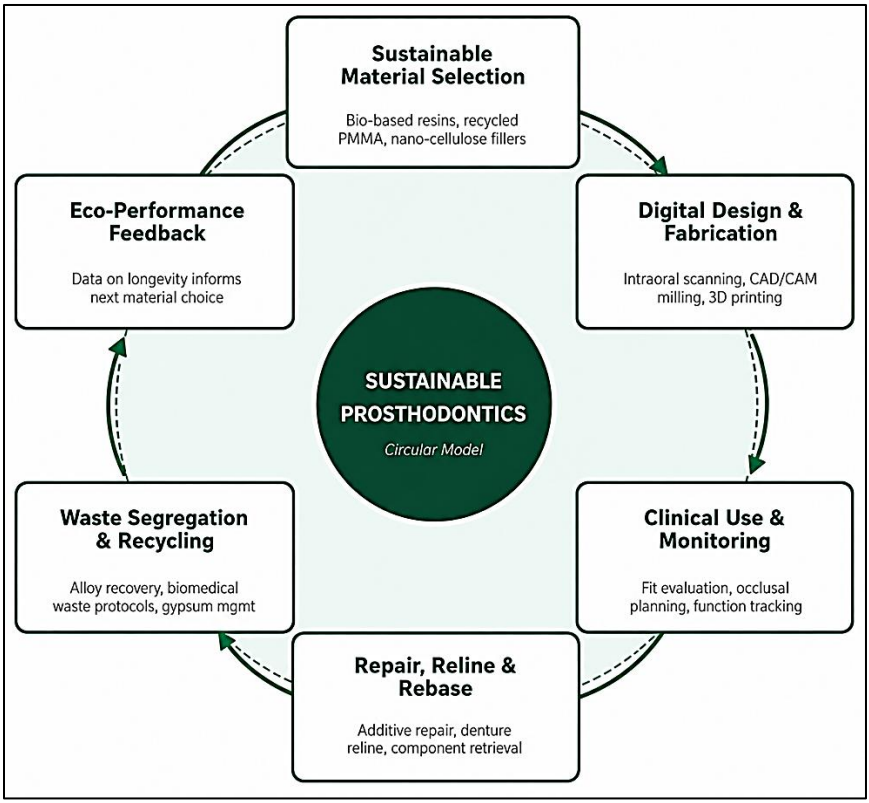

Figure 1.1: Circular model

Table 3: Digital technologies in prosthodontics and their sustainability profiles

Digital Technology	**Eco-advantage**	**Prosthodontic Use**	**Barrier to Adoption**
Intraoral scanners	Eliminates impression waste	Full-arch impressions	Learning curve
Milling (CAD/CAM)	Precise material use	Crowns, bridges, dentures	Milling bur wear
Additive 3D printing	Minimal post-fabrication waste	Surgical guides, bases	Resin toxicity concerns
Virtual articulation	Reduces remakes	Occlusal planning	Cost of software

Table 3 compares digital technologies with reference to their sustainability profiles.

Figure 1.2 contrasts the conventional and digital prosthodontic fabrication pathways and highlights the waste-, energy-, and chemical-reduction points at each stage.

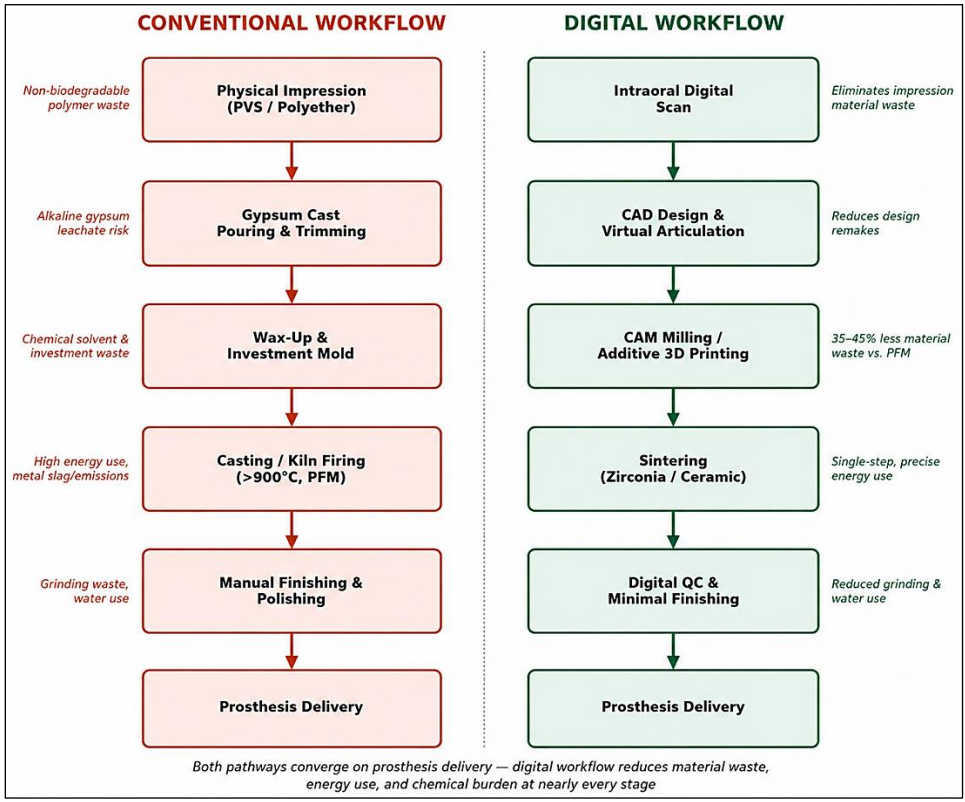

Figure 1.2: Conventional vs. digital workflow

Energy Efficiency and Green Laboratory Practices

Dental labs use energy on their milling machines, sintering furnaces, autoclave, light-curing units and climate control systems. In a European multi-chair prosthodontic clinic, the energy consumption of laboratory equipment was comprehensively examined and it was found that the energy use of the sintering furnace and milling machines accounted for more than 60% of the total laboratory energy consumption [25].

Energy management systems, furnace programming for shut-off during non-productive hours, and investments in PV or other renewable energy supplies for the power supply to all laboratory equipment are legitimate, effective measures to make the work space more environmentally friendly [26,27].

The amount of water used in traditional prosthodontic lab is significant, especially when trimming models, grinding surfaces and cooling handpieces. Water usage in dental laboratories can be cut by 40 to 60% with closed loop water recycling for model trimmers and low water rinsing for impression materials and casts [28].

Longevity, Repairability, and the Circular Prosthetic Model

While a pro-theoretical sustainable approach to prosthodontics places greater emphasis on the lifespan of the restorations as opposed to routine replacement. The idea of a circular prosthetic model – that prosthetic device be repaired, rebased and/or relined, not thrown away – reflects broader concepts of a circular economy which are increasingly part of the fabric of industrial policy [29].

For instance, complete dentures require a lot of material and labor. Instead of prescribing new prostheses, the practice of rebase and reline of worn ill-fitting dentures can help extend the service life of dentures and significantly lower material use. Relined dentures have been shown to equal the patient satisfaction scores of recently fabricated ones, especially when sufficient occlusal stability and retention are obtained [30].

In the case of fixed prostheses, the new paradigm of additive repair (additive manufactured composite or ceramic patches) is a minimally invasive approach that extends the lifespan of crowns and veneers after chipping or marginal wear, with the added benefit that a portion of the fixed investment may be reused at the component level without loss in overall material consumption across the prosthesis life cycle [31,32]. For implant-retained prostheses, when designed with retrievability as one of the primary considerations, component-level replacement of unwanted superstructures or abutments is possible without loss of overall investment over the life cycle.

DISCUSSION

The overall conclusions of this review strongly support that a sustainable prosthodontics is a complex process that covers materials science, clinical workflow design, waste management, energy governance and patient-driven longevity planning. Scientifically viable and clinically sound shifts from consumption to use and then to disposal to a more circular and ecologically responsible model.

In biomaterials, Researchers have found that denture base resin using nano-cellulose had flexural strength values within 12% of standard heat-cured PMMA denture base resin, and had significantly reduced monomer release, making them clinically viable [33]. Likewise, authors also reported that, under standardized ISO testing conditions, recycled-content PMMA disc blanks for CAD/CAM milling had mechanical properties comparable to their virgin counterparts, indicating that it can be technically feasible for the industry to recover material at large scale [34].

While these advances have been made, there are still obstacles to sustainable adoption. The biggest challenge is cost: For a solo practitioner or underserved clinic, the capital cost of an intraoral scanning system, CAD/CAM milling unit and 3D printing platform is too expensive [35]. Taking steps to close this equity gap will require policy measures beyond just providing free or low-cost equipment to the poor, such as making equipment available at public health facilities and by coordinating procurement through the dental schools and teaching hospitals [36].

Another major lack is the lack of agreed-upon eco certification requirements for dental materials. Whereas there are established green certification schemes in the construction or food sector that support consumer and professional decision making, there are no such schemes in dentistry [37]. Standardized ecological performance indicators for the use of prosthetic materials would enable clinicians and procurement officers to make informed decisions based on ecological considerations. Table 4 summarizes the major barriers and offers possible solutions, and Table 5 lists priority strategies for integrating sustainability into the practice of prosthodontists.

Table 4: Barriers to sustainable prosthodontics and proposed solutions

Barrier	Impact Level	Proposed Solution	Responsible Party
High cost of digital equipment	High	Institutional investment schemes	Dental schools, hospitals
Lack of standardized eco-protocols	High	Regulatory framework development	Professional bodies
Limited clinician awareness	Moderate	CME and workshop training	Dental councils, colleges
Patient preference for conventional materials	Moderate	Patient education programs	Clinicians, public health bodies

Table 5: Priority strategies for sustainable prosthodontic practice

Strategy	Immediate Benefit	Long-term Outcome	Priority Level
Adopt digital workflows	Waste elimination	Net-zero laboratory	High
Use sustainable biomaterials	Reduced chemical burden	Improved biocompatibility	High
Implement waste segregation	Regulatory compliance	Community health protection	Moderate
Promote repair over replacement	Reduced prosthesis turnover	Cost savings for patients	Moderate

CONCLUSION

This chapter shows how sustainable prosthodontics is a real necessity and the professional correct way of the science. Implementing eco-friendly biomaterials, digital workflow technologies, comprehensive waste segregation and recycling initiatives, as well as energy-efficient lab practices can all significantly and effectively minimize the environmental impact of the dental prosthetics sector. Promotion of prosthesis longevity and repairability and recyclability of its components, is consistent with recognized principles of the circular economy and the environment, globally. Significant progress will take a complex process of collaboration among clinicians, dental educators, material manufacturers, regulatory agencies, and health system administrators. Real-world performance testing of sustainable materials and technologies to support evidence-based guidelines and facilitate rapid transition of prosthodontic practice toward a more responsible approach is urgently needed.

❑❑❑

CHAPTER 2

PATIENT ASSESSMENT AND TREATMENT PLANNING

INTRODUCTION

This chapter provides the grammatical structure, which is the systematic way in which a raw clinical record is transformed into a safe, predictable and prosthetically sound treatment plan [1]. Above all else, implant dentistry is prosthetically guided, and the final restoration and esthetic and functional requirements dictate the position, number and angulation of the implant. A structured workup that involves a clinical exam, medical risk assessment, radiographic and 3D imaging, diagnostic wax-ups and digital smile design, and an honest and evidence-based assessment of case difficulty are essential to achieving this.

This chapter moves through that workflow as one might perform in clinical practice: clinical evaluation of the patient and the proposed treatment site; medical history and modifiable and non-modifiable risk factors; radiographic evaluation with particular emphasis on cone-beam computed tomography, or CBCT; diagnostic wax-ups and digital smile design as tools for prosthetically-driven planning; the range of surgical guide options available to translate a digital plan into the surgical field; and finally, a structured framework, the SAC classification, for judging overall case complexity and matching it to clinician experience.

The humerus displays a wide variety of fractures and injuries. The humerus has a wide range of fractures and injuries.

Extraoral and Intraoral Clinical Examination documents the evaluation of any abnormal extraoral and/or intraoral findings.

Like all dental assessment, the clinical workup starts extra orally, where the assessment of facial symmetry, lip support, the smile line (how much of the gingiva and tooth structure will be seen when the patient is smiling), and temporomandibular joint function are all relevant to both surgical and prosthetic planning. In particular a high smile line raises the esthetic challenges of the treatment of the anterior implant, and should be documented early as it will directly influence the visibility of any deficiency in the soft tissue contour and/or the implant-crown emergence to the patient [3].

Inside the mouth, the site to be assessed and surrounding area should be evaluated systematically: Form and width of the edentulous site (which is frequently assessed visually and by manual palpation and confirmed radiographically), amount and quality of

keratinized mucosa, thickness versus thinness of soft tissue biotype (the latter is more likely to show recession and less tolerant of surgical or prosthetic error), and the health of the periodontium of adjacent and opposing teeth. The biologic width analogue (BWA), which develops around an Osseo integrated fixture, has been quantified, along with the dimensions of the peri-implant soft tissue complex, which can be used as a reference when assessing soft tissue adequacy at a given site [4]. The clinical picture is completed with the occlusal analysis, including an analysis of any parafunctional habits, arch relationships and available interocclusal and interradicular space, which is directly related to the prosthetic feasibility [5].

The vertical and horizontal dimensions of the planned restoration are very important; if the interocclusal dimension is too small, a screw-retained design might not be possible or could require occlusal adjustment prior to implant placement; if there is not enough mesiodistal space between adjacent roots, implant diameter selection or up righting of tilted teeth with orthodontics may be compromised. Generalized wear facets, fractured restorations, or masseteric hypertrophy- signs of active or historical parafunction should be documented explicitly, as these factors will have an impact not only on surgical risk, but also on the selection of the type of prosthetic material and the protocol for long term maintenance.

Photographic and, if necessary, video documentation should be routinely collected as part of this examination, as a medico-legal tool and also as a tool to communicate during the diagnostic wax up process and the digital smile design process. As a baseline for future treatment progress and/or final evaluation, a standardized set of views (full face at rest and smiling, retracted views of the front and sides of the mouth, and an occlusal view of the edentulous site) creates a reproducible view, enabling the clinician to take his time and review esthetically relevant details (such as the exact exposure of gingival tissue on a broad smile) during the chairside impression phase [7].

A medical history and risk factor assessment must be performed for every patient prior to treatment.

A detailed medical history is not a "routine" but rather an integral part of the surgical risk stratification process. Many clinics employ the American Society of Anesthesiologists (ASA) Physical Status Classification System, which was developed to assess anesthetic risk levels, but which is now commonly used in oral surgery and implant dentistry as a simple shorthand for overall systemic health ranging from ASA I (a normal healthy patient) to ASA III (a patient with severe systemic disease), and so on, with ASA III and above usually requiring closer medical liaison or, in some cases, treatment in a hospital-based setting [8,9]. In addition to this broad classification, a number of specific types of medical

risk warrant special consideration in implant candidates, which is summarized in several reviews of medical contraindications to implant therapy.

Elevated glycated hemoglobin (HbA1c) also has been shown to be linked to impaired microvascular healing, altered collagen metabolism, and have measurably increased risk of early implant failure and peri-implant disease; well-controlled diabetes, on the other hand, does not seem to be an absolute contraindication, and can be associated with implant survival rates similar to those of non-diabetic patients [10]. Patients taking antiresorptive or antiangiogenic agents (most commonly bisphosphonates or denosumab for osteoporosis or for skeletal metastases in oncologic disease) have a small but clinically significant risk of MRONJ following any bone-invasive procedure (such as implant placement), with high dose intravenous oncolic doses having a much greater risk than standard oral osteoporosis doses; there exists a structured approach to risk stratification and informed consent in this patient population [11].

Bleeding risks must be taken into consideration with anticoagulant and antiplatelet agents, and in most situations should be coordinated between the dental team and the prescribing physician, as there is a competing risk for thrombosis of stopping these medications. Patients who are immunocompromised (e.g., those who have undergone organ transplants, those with uncontrolled HIV infection, or those undergoing active chemotherapy) have a higher risk for infection and a potential, but less precisely understood, risk of osseointegration problems [12].

Cigarette smoking is one of the most consistently replicated predictors of implant complications in the literature, smoking results in a decrease in peripheral blood flow and an impairment in wound healing via both vasoconstrictive and direct cytotoxic mechanisms, and is associated with significantly higher implant failure rates in the maxilla since the early large case series [13]. This has been confirmed in subsequent systematic reviews and meta-analyses with a pooled large dataset, as well as the presence of a dose-response relationship and an increased risk of peri-implant marginal bone loss and peri-implantitis in continuing smokers. Smoking cessation counselling should be part of informed consent and, so far as is possible, actively encouraged for a period of time in the lead up to the surgery [14].

Structured risk-assessment frameworks, like the one proposed by categorize implant risk factors as general (systemic), local, and site-specific and offer a simplified method to account for their cumulative impact on treatment planning, are useful conceptual tools in organizing this multitude of variables to form a coherent risk profile. Table 2.1 lists the main categories of medical and behavioral risk that are relevant to implant candidates.

Table 2.1: Key medical and behavioral risk factors in implant patient assessment

Risk Category	Specific Factor	Relevance to Implant Therapy
Systemic – metabolic	Poorly controlled diabetes mellitus (HbA1c > 8%)	Impaired microvascular healing and collagen synthesis; associated with higher early failure and peri-implantitis risk
Systemic – bone-modifying therapy	Antiresorptive/antiangiogenic agents (bisphosphonates, denosumab)	Risk of medication-related osteonecrosis of the jaw (MRONJ), particularly with high-dose intravenous oncologic regimens
Systemic – hematologic	Anticoagulant or antiplatelet therapy	Increased intra- and post-operative bleeding risk; may require medical liaison before surgery
Systemic – immune	Immunosuppression (transplant recipients, uncontrolled HIV, chemotherapy)	Elevated infection risk and potentially impaired osseointegration
Behavioral	Cigarette smoking	Reduced peripheral perfusion; dose-dependent increase in implant failure and marginal bone loss
Behavioral	Parafunction (bruxism, clenching)	Excessive occlusal loading; increased mechanical complication and crestal bone loss risk
Local / anatomical	Active periodontal disease, thin soft tissue biotype, limited keratinized mucosa	Higher susceptibility to peri-implant mucositis and peri-implantitis; esthetic risk in thin biotypes

Although cardiovascular disease is prevalent in older patients who are candidates for implant, it does not usually preclude the implantation process and in many cases is well controlled; the more important concern is the antithrombotic medication required by these patients and the need to effectively manage stress and control blood pressure during the surgical procedure, especially when vasoconstrictor-containing local anesthetic is utilized [15]. Generally, surgical procedures involving the implantation of any type of surgical

device are postponed until blood pressure is under control, and the physician confirms that there is no unstable angina, a recent myocardial infarction, or recent cerebrovascular events [16]. Similarly, inherited and acquired bleeding disorders (e.g., hemophilia and von Willebrand disease) need pre-operative hematologic evaluations for management of their bleeding disorder before surgery and, in many cases, specific factor replacement or perioperative management protocols coordinated with the patient's physician [17].

RISK COMMUNICATION AND INFORMED CONSENT

The identification of a risk factor is only part of the clinical responsibility, with the other part being clearly conveying the meaning of the risk factor to the patient so that informed consent is truly obtained [18]. This should include a frank discussion of the potential for failure to increase by such modifiable behavioral risk factors as smoking and an explicit recommendation for either quitting smoking or not smoking before and after surgery [19]. When a systemic risk is not modifiable or can be modified only limits to the extent, informed consent should include a clear, documented discussion of the specific risk (for example, a history of bisphosphonate therapy), any measures taken to minimize the risk (such as a drug holiday, where appropriate and medically feasible, or an ongoing relationship with the prescribing physician), and the recognition that there may still be residual risk despite those efforts [20]. The documentation of this discussion in the clinical record is good practice and an important medico-legal safeguard.

Please select the imaging modality that is the most suitable for the case. 2.4.1 Choose the most appropriate imaging modality.

The selection of the imaging modality should be based on the principle of selection criteria, where the imaging technique chosen should be the one that is necessary and can be performed at the minimum reasonable radiation dose and not necessarily the most advanced technique available for each case [21]. While periapical radiographs will remain useful for fine-detail analysis of a single site, especially when used for follow-up, panoramic radiographs will prove useful for a general overview of both arches, but will have magnification distortion, geometric superimposition, and be unable to assess buccolingual dimension — they should not be the sole basis for treatment planning for most implants [22].

When a three-dimensional image is needed for implant planning, cone-beam computed tomography (CBCT) is the imaging technique of choice because it provides sub-millimeter accuracy in determining bone volume, density and the location of important anatomical structures with a significantly reduced radiation dose compared to conventional medical computed tomography (CT) [23]. Major radiologic and implantology groups have provided consensus guidelines that suggest that for most implant cases, beyond the most common

single-tooth situation, CBCT is warranted when there is a clear value added in terms of diagnostic benefit, and not recommended to be routinely obtained when the gain in diagnostic information is minimal and the radiation, cost, and interpretation burden is not. Major radiologic and implantology societies have provided consensus guidelines suggesting that for most implant cases, beyond the most common scenario of the single tooth in an obviously adequate site, CBCT should be used only when there is a clear advantage in the added diagnostic information and is not recommended for routine use when this advantage is minimal, and the increased radiation exposure, cost, and interpretation burden is. Table 2.2 shows a comparison of the different major imaging modalities available today for implant planning.

Table 2.2: Comparison of radiographic modalities used in implant treatment planning

Modality	**Dimensionality**	**Typical Radiation Dose**	**Primary Clinical Use in Implant Planning**
Periapical radiograph	2-dimensional	Very low (~1–8 µSv)	Fine detail of a single site; post-operative and follow-up assessment
Panoramic radiograph	2-dimensional (tomographic)	Low (~10–25 µSv)	Broad screening view of both jaws; initial case overview and gross pathology
CBCT (limited field of view)	3-dimensional	Moderate (~20–100 µSv)	Site-specific bone volume, density, and vital structure localization for single/multiple implants
CBCT (large field of view)	3-dimensional	Higher (~70–600 µSv)	Full-arch or complex reconstructions; comprehensive assessment of the maxillofacial skeleton

RADIATION SAFETY AND THE ALARA PRINCIPLE

Implant planning related to all kinds of ionizing radiation should be guided by the ACR principle— As Low as Reasonably Achievable — which means that the clinician is obliged to justify each exposure based on an actual diagnostic need and is required to acquire the necessary information using the smallest possible field of view, voxel size, and exposure settings. In practice this usually results in choosing the smallest field of view that will include the region of interest of surgical interest, as the dose varies significantly with the

volume of tissue irradiated, and large field of view scans are not necessary for a single tooth case for which a limited volume scan would be adequate [24]. This is especially important as implant patients might also need multiple imaging assessments during the course of treatment planning, surgery and long-term follow-up, and total dose throughout the entire treatment should be taken into consideration from the outset [25].

SYSTEMATIC CBCT INTERPRETATION

When interpreting a CBCT for implant planning, it is important to follow a systematic or orderly approach rather than a visual scan. Site-specific analysis should follow incidental path analysis of the entire dataset, which is a legal and ethical responsibility, as well as a clinical one. Most common site-specific factors that need to be measured include available bone height (from the alveolar crest to the relevant limiting structure, which is usually the inferior alveolar canal, the mental foramen, or the maxillary sinus floor), buccolingual ridge width at the level of the planned implant platform, and the three-dimensional relationship of the proposed implant position to adjacent tooth roots and vital structures [26].

To account for the error in measurement and anatomical variation, a minimum safety margin is usually maintained of about 2 mm from the apex of the implant to either the inferior alveolar canal or other critical structures. The main measurements made on a cross sectional CBCT slice are shown in Figure 2.1 during pre-surgical preparation.

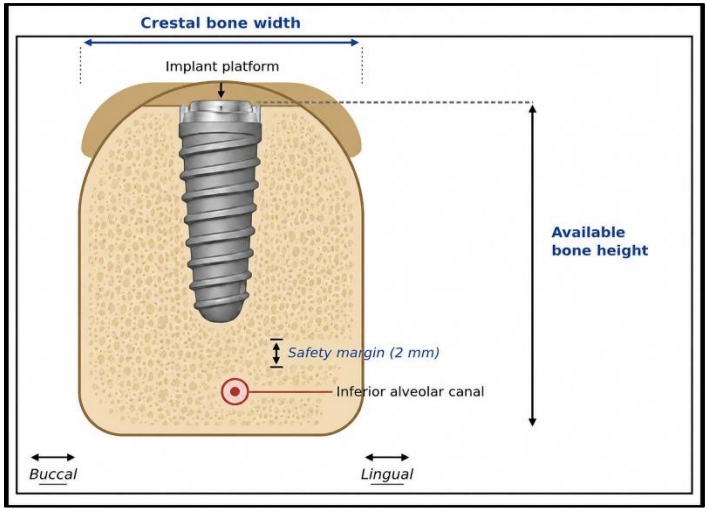

Figure 2.1: CBCT cross sectional analysis of the important linear measurements used for presurgical planning: crestal bone width, available bone height and safety margin to the inferior alveolar canal

Diagnostic Wax-Up or Digital Smile Design

Since the treatment plan should be prosthetically directed, there are more reliable ways to build a treatment plan backwards from the intended final prosthetically directed treatment plan rather than forwards from available bone. Because the diagnostic wax-up is a physical or digital model of the planned final tooth position and contour created on a study cast or scanned model, it remains one of the most simple and effective tools, providing a visual and communication aid for the clinician to demonstrate the desired outcome, evaluate the amount of space available for the restoration, and create a radiographic or surgical guide directly from the planned tooth position [27].

Digital smile design is an extension of this concept into a digital workflow, in which pre-treatment standardized protocols of the patient's face and smile are captured by photographs and video, and then overlaid with a proposed tooth position and proportion, for the purpose of collaboratively planning esthetic outcomes with the patient prior to initiating any irreversible treatment. Digital smile design data can also be combined with CBCT and intraoral scan data to create digitally a fully prosthetically driven position of the implants, the equivalent of the traditional wax-up-to-surgical-guide workflow, and the basis of the following guided surgery protocols [28].

In reality, the integrated digital workflow is usually carried out in a series of separate steps: acquisition of standardized 2D facial and smile photography or video; digital design of the proposed tooth arrangement, in which the facial and dental proportion analysis were used as key tools; superimposition of an intraoral scan of the existing dentition and facial soft tissue; fusion of the surface scan with the CBCT data set by relating them to shared anatomical or fiducial reference points; and lastly, virtual implant positioning within this composite model, respecting the prosthetic envelope defined by the digital design and the anatomical constraints defined by the CBCT. The product of this process is a virtual implant plan that can be directly exported for guide fabrication, bringing the esthetic design process into the surgical workflow, discussed throughout this chapter.

Surgical Guides

After a position for the prosthetically driven implant has been determined either with a conventional wax-up or a digital planning workflow, this position needs to be transferred consistently to the surgical field. The original planning systems in the early 2000s started to allow the fabrication of a physical surgical guide directly from segmented CT data, thus enabling the position of the planned implant to be reproduced in surgery with a degree of precision that could not be achieved by freehand judgement [30]. Today, there are three levels of surgical guides: simple pilot (point entry) devices that place the initial entry point and angulation only, partially guided devices that control the entire osteotomy but allow the final implant angulation based on the surgeon's judgment, and fully (statically) guided devices that control all drills and the final implant placement via a guide sleeve.

Table 2.3: Comparison of surgical guide types by level of control

Guide Type	Level of Control	Fabrication Method	Typical Indication
Freehand placement	Surgeon judgment only, no physical guide	None (mental positioning from imaging and clinical landmarks)	Straightforward single-tooth cases with abundant bone and favorable anatomy
Pilot (point-entry) guide	Controls entry point and initial angulation only	3D-printed from digital plan; guides only the initial pilot drill	Cases requiring some flexibility to adapt depth/angulation after initial osteotomy
Partially guided (pilot + sequential drills, freehand implant seating)	Controls osteotomy trajectory; implant placed freehand	3D-printed surgical template with sleeves for sequential drills	Moderate-complexity case benefiting from guided drilling but surgeon-controlled seating
Fully (statically) guided surgery	Controls entire osteotomy sequence and final implant seating depth/rotation	3D-printed template referencing teeth, mucosa, or bone; sleeve-in-sleeve drill system	Complex or multiple-implant cases, minimally invasive flapless protocols
Dynamic navigation	Real-time tracked instrument position displayed on screen; no physical template	Optical/infrared tracking system referencing a fiducial marker on the patient	Cases requiring intra-operative flexibility with digital accuracy, edentulous arches

Another and growing practice are dynamic navigation, in which no physical template is involved, and the position and trajectory of the handpiece is shown in real time relative to the pre-operative plan on a monitor in the chairside area, enabling the surgeon to interactively adjust the osteotomy, while still gaining all the advantages of digital accuracy. Static computer-aided implant surgery systematics have generally reported clinically acceptable accuracy (mean deviation, 1-2 mm at the implant platform and slightly larger at the implant apex, depending on the considerable accuracy influence factors that are the

guide support type (tooth-, mucosa-, or bone-supported), flap status, and clinician experience) [31]. With in-facility and laboratory 3D printing becoming easily accessible, the cost and time involved in the creation of these guides has been significantly lowered, paving the way for their broader use in everyday practice.

It is important to point out that the use of a surgical guide, even if it is very accurate, is not an alternative to good clinical judgment and correct planning, the same error that is included in the digital plan will be transferred to the surgical field using the same precision [32].

Irrespective of the type of guide used, it is pivotal that it is confirmed that it fits properly, without rocking, interference, or soft tissue contact on the day of surgery, on the teeth, mucosa, or bone. Several other protocols call for a radiograph or radiograph scan with a radiographic marker placed in the guide before the surgery to validate the plan and ensure the fabricated guide is correct [33] and the guide should be placed ambiguously or with some detectable movement to introduce positional error similar to freehand placement, while giving the surgeon a false sense of certainty.

The SAC Classification follows the criteria established by the case selection criteria. The case selection criteria form the basis of the SAC Classification.

After collecting the above clinical, radiologic and prosthetic data, the clinician must make a sincere determination of the overall level of difficulty of the case and whether this case is within their scope of training, experience and resources. The most popular system for this classification was developed by the International Team for Implantology (ITI), which categorizes implant cases into three levels of difficulty: Straightforward, Advanced, and Complex, reflecting the combined effect of risk factors from medical, anatomical, esthetic, and restorative aspects [34].

The cases in which the patient is healthy, with no other systemic risk factors, no other reason to augment the bone volume and quality, low esthetic demand, and the most basic single-unit or simple prosthetic reconstruction are considered straightforward cases, which are suitable for clinicians with basic implant training. Advanced cases are those with one or more moderate risk factors, which are a controlled systemic condition, a minor bone/soft tissue deficiency that can be corrected simultaneously or staged over a short period of time, or moderate esthetic demands in the premolar or canine area; are best managed by clinicians who have additional experience or proper mentorship. Complex cases involve high systemic risk, major hard and soft tissue deficit and a need for extensive grafting, high esthetic risk (thin biotype, high smile line, missing interdental papillae), or complex full-arch restorative needs, and are best suited for specialists or clinicians with advanced and dedicated training [35].

The esthetic part of a case's complexity should be especially highlighted because esthetic failure is one of the most frequent reasons for patient dissatisfaction even in the absence of implant complications or osseointegration failure. Risk assessment tools that have been structured and

validated to anterior single-tooth implants include those that assess the smile line, gingival biotype, tooth and papilla form, bone level adjacent to neighboring teeth, and the shape of the edentulous defect [28]. Case selection also overlaps with decisions regarding treatment timing (e.g., immediate vs. early vs. late) as well as loading protocol (e.g., early vs. late), each of which will affect the effective challenge of an otherwise comparable case and for which there is a significant each protocol [36]. The SAC framework and key determinants are summarized in Table 2.4 and Figure 2.2.

Table 2.4: The SAC classification: Domains and defining criteria

Domain	**Straightforward (S)**	**Advanced (A)**	**Complex (C)**
Medical status	ASA I, no relevant risk factors	ASA II, one or more controlled risk factors	ASA III or uncontrolled/multiple risk factors
Bone volume	Adequate width and height, no augmentation needed	Minor horizontal or vertical deficiency requiring simultaneous or staged minor augmentation	Severe atelectasis-level deficiency requiring major grafting (block graft, sinus lift, vertical GBR)
Esthetic risk	Low (posterior, low smile line, thick biotype)	Moderate (premolar/canine region, average smile line)	High (anterior maxilla, thin biotype, high smile line, missing papillae)
Restorative complexity	Single implant, standard prosthesis	Short-span fixed partial denture or moderately complex full-arch case	Full-arch rehabilitation, complex occlusal scheme, or combination with orthodontic/orthognathic treatment
Recommended operator level	General dentist with basic implant training	General dentist with additional implant experience/ mentorship	Specialist or clinician with advanced, dedicated implant training

RECOGNIZING THE NEED FOR INTERDISCIPLINARY REFERRAL

A candid application of the SAC framework will, in a meaningful proportion of cases, indicate that a plan is best executed jointly with, or referred entirely to, another specialist. Common triggers for interdisciplinary involvement include active or unresolved periodontal disease requiring specialist periodontal management before implant therapy proceeds, orthodontic space or root-angulation problems that would compromise implant position if not corrected first, skeletal discrepancies warranting orthognathic evaluation, and any case combining several Complex-tier risk factors simultaneously, such as a medically compromised patient requiring major bone augmentation in a high esthetic zone [37]. Recognizing these triggers early-ideally during the initial clinical evaluation described, rather than after treatment has already begun is itself a marker of sound clinical judgment and is fully consistent with the evidence-based, prosthetically-driven philosophy underlying this entire chapter.

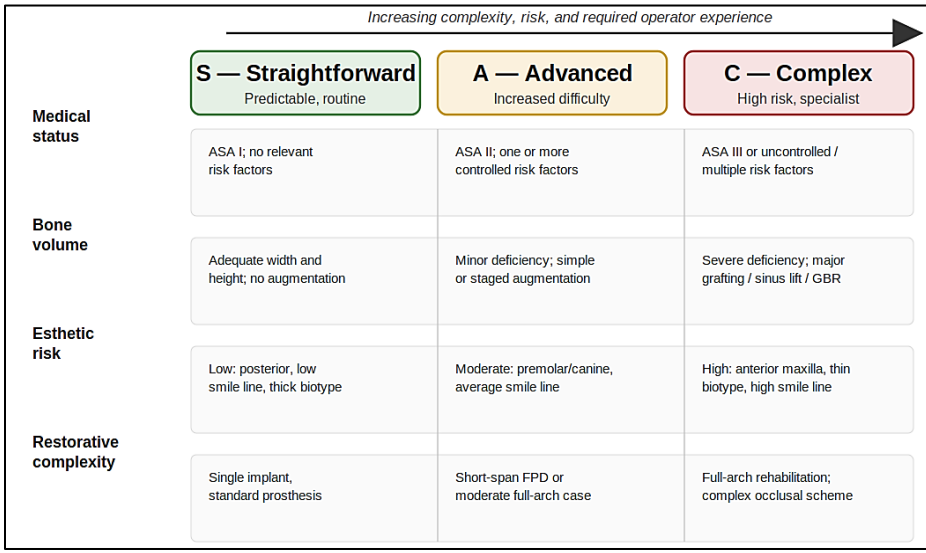

Figure 2.2: The SAC classification framework, illustrating the progression from straightforward through advanced to complex cases across medical, anatomical, esthetic, and restorative domains

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CHAPTER 3

BASIC SURGICAL MANEUVERS AND IMPLANT PLACEMENT

The principles of the biological and the planning that were discussed in the preceding chapters are materialized into a result during the surgical placement of an implant. All the manoeuvres are simple in isolation, but their sum is the key to determining whether osseointegration will take place or not: preparation of the sterile field, raising and management of the flap, cutting the precise osteotomy without harming the bone and seating the fixture at the correct three-dimensional position with the right stability. These basic maneuvers are described here in the order they are performed, and the decisions made that define these maneuvers are outlined: where to make the incision, how to drill without overheating the bone, how much primary stability to aim for, whether to immerse the implant, and when to implant, relative to tooth extraction.

INTRODUCTION

At its most basic, implant surgery is a planned wounding procedure that is performed in circumstances which are optimized for a bony healing process rather than a fibrous healing process [1]. It is not only one innovation that provides predictability in modern implant therapy, but the careful execution of a well-documented protocol for atraumatic surgery, site preparation, primary stability and healing period which have been developed over many decades of clinical research. Long-term data, that laid the foundation for the reliability of clinical outcome of osseointegration, have been produced by such protocols [2].

The maneuvers described in this chapter are most applicable to the simple insertion of a single implant or a few implants in a healed, properly sized ridge — the situations that every new implantologist should be able to handle first. In Chapter 4 more advanced cases of significant bone and soft-tissue loss and the grafting methods that are employed to deal with these are discussed. Here the main points are on the preparation of the environment and of the instruments, the access to and management of the tissues, the cutting of the osteotomy, the positioning and seating of the implant, and the selection of the healing configuration [3].

This course focuses on the principles of asepsis, infection control, and the surgical environment.

Placement of implants involves putting a foreign body into a surgical incision formed in the bone, which requires simple control of contamination to be one of the essential conditions for the procedure. Because the oral cavity cannot be rendered sterile, the implant surgery is carried out applying a clean technique that involves the use of sterile instruments, a sterile implant (fixture) and precautions to minimize intra-oral contamination while protecting the surgical field from external contamination [4].

Aseptic precautions have been directly studied regarding the intensity. In one of the most frequently quoted comparison, Scharf and Tarnow were unable to find the difference in osseointegration success between implants placed under fully sterile operating-room conditions and those placed under the clean, office-based protocol, as long as basic principles of sterile instrumentation and field control were followed. This discovery reinforces the importance of preparing the dental surgery correctly for the routine installation of an implant and the critical importance of the sterility of the instruments in contact with the osteotomy site and the implant [5].

PRACTICAL MEASURES FOR FIELD CONTROL

In practice the infection control measures used for implant surgery involve a number of complementary steps: use of sterile surgical instruments and drills; sterile handling of the implant which is delivered in a sterile container, and cannot come into contact with non-sterile surfaces or, in the case of titanium, be contaminated; pre-operative reduction in the oral bacterial load, usually by using an antiseptic mouth rinse (chlorhexidine); disinfection of the peri-oral skin and sterile draping; and use of sterile gloves, gown, and copious sterile irrigant during osteotomy preparation. Throughout the surgical field, saliva and debris are excluded [6].

ANTIBIOTIC PROPHYLAXIS

Prophylactic antibiotics at the time of implant placement is still a matter of debate. In a Cochrane systematic review, it was found that taking one dose of an antibiotic before the surgery helps to protect against early implant failure; however, the benefit was small and there are potential risks of side effects and antimicrobial resistance. Current practice thus leans toward a single pre-operative dose for simple cases, and the regimen individualized on the basis of patient's medical status, the complexity of the surgery and prevailing guidelines. The use of antibiotics is not a replacement for good aseptic technique [7].

SURGICAL ARMAMENTARIUM

The correct and properly maintained instruments must be ready and organized in advance of surgery for a predictable procedure. In addition to the general oral-surgery set used for local anesthesia, preparation of the incisions and reflection of the flaps, there is a special

implant surgical set usually system-specific consisting of the necessary drills, depth gauges, direction indicators, drivers and torque-measuring device for the particular implant selected [8].

Table 3.1 shows the instruments that are typically used during a simple implant placement, organized by the phases in which they are used.

Table 3.1: Shows the basic surgical armamentarium for implant placement

Stage	Instruments / Items	Function
Anesthesia & asepsis	Syringe with local anesthetic; antiseptic rinse; sterile drapes, gown, and gloves	Control of pain, reduction of bacteriological load, and maintenance of a sterile surgical field
Incision & reflection	Scalpel (e.g., No. 15 blade); periosteal elevator; tissue retractors; surgical suction	Provides access to the alveolar crest, facilitates flap reflection, and maintains clear surgical visibility
Osteotomy preparation	Surgical handpiece and motor; sequential (graded) drills; direction/parallelism pins; depth gauge; copious sterile irrigant	Precise and atraumatic preparation of the implant osteotomy to the planned depth and angulation
Implant placement	Sterile implant fixture; implant driver/mount; handpiece adapter or ratchet; torque wrench	Placement of the implant fixture and verification of insertion torque to achieve primary stability
Closure	Cover screw or healing abutment; suture material; needle holder; scissors	Placement of healing component and closure of the surgical wound to promote uneventful healing

There are two guiding principles that are important to keep in mind when using this armamentarium. First, drills are consumable, so they need to be sharp; not only because more heat is produced when they are blunt, but also because the pressure will need to be increased, which will be harmful to the bone. Manufacturers have only a finite number of uses listed that once reached, drills should be scrapped [9]. Second, the sequence and size of the drills is specific to the system and should be performed according to their instructions; the osteotomy sequence has been designed to prepare the site for the subsequent drill, ending in an osteotomy similar to the geometry of the specific implant.

While detailed assessment of the radiograph is a part of the planning of Chapter 2, the surgeon is mindful of the relevant anatomy all of the time that they control their placement. For preparation in the mandible, the limits of safety are the inferior alveolar nerve, inferior alveolar foramen, the lingual concavity of the posterior body, and the sublingual and submental vasculature of the floor of the mouth [10]. The maxillary sinus and the nasal floor reduce the vertical dimension in the maxilla and the midline is restricted by the incisive canal. Damage to these structures due to direct instrumentation or to perforation of a cortical plate is one of the major sources of severe surgical complications, and respecting a safety margin from both is one of the basics of instrumentation.

The surgeon performs a medical evaluation and obtains informed consent from the patient immediately prior to surgery, confirms the location of the implant with the diagnostic and radiographic records, and — if a surgical guide has been fabricated — checks fit and seating of the surgical guide. Deep local anesthesia is achieved. In the mandible, infiltration is sometimes preferred at the posterior sites as an additional warning will be provided were the drill to approach the inferior alveolar nerve, while providing adequate operative comfort.

FLAP DESIGN AND INCISIONS

A mucoperiosteal flap is typically used to gain access to the alveolar crest. The design of that flap is a deliberate compromise between competing goals as it must allow for visibility of the bone ridge, to ensure that the preparation is correct and safe, as well as maintain the blood supply to the tissues, protect surrounding structures and allow tension-free closure with an acceptable and aesthetically pleasing outcome. The basic designs are shown in Figure 3.1 [12].

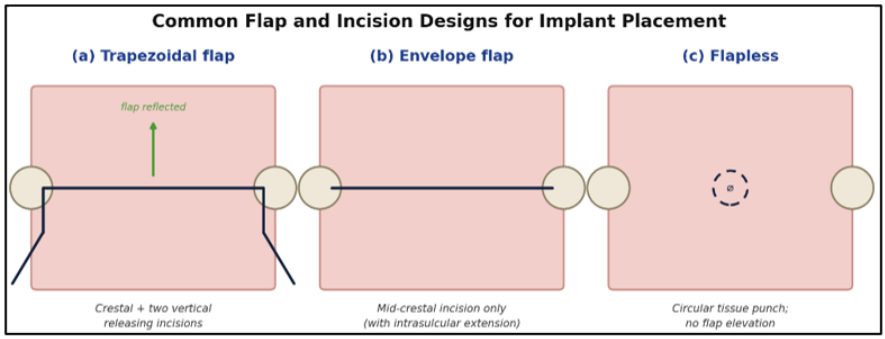

Figure 3.1: Common flap and incision designs: (a) a trapezoidal full-thickness flap with a mid-crestal incision and two vertical releasing incisions; (b) an envelope flap raised from a crestal incision with intrasulcular extensions and no releasing incisions; (c) a flapless approach using a circular tissue punch

Principles of Flap Design

Blood vessels of the mucoperiosteum are mostly parallel to the long axis of the teeth and the tooth crest. Incisions should then be made with as much consideration to this pattern as possible, and the base of any flap should be at least as wide as the free margin, to ensure good flap perfusion [7]. A full-thickness (mucoperiosteal) flap is raised by sharp incision to the bone and periosteum bluntly elevated to expose the crest cleanly, which is the usual technique for most placements. Flaps should be only partially reflected and handled carefully, and kept moist while handling [13].

Wound edges should overlap at closure, as they must close tightly and under no tension, as it will affect the blood supply and lead to dehiscence and uncovering of underlying bone or grafts. Periosteal releasing incisions at the base of a flap can be used to increase the passive extensibility of a flap, and allow tension-free primary closure, where this has been done to cover a graft, for example.

Incision Types

The crestal (mid-crestal) incision, which runs along or slightly palatal/lingual to the crest of the ridge and divides the keratinized tissue, leaving sufficient attached mucosa buccal and lingual of the future implant is the most common and basic incision used for implant access [14].

Alternatively, an envelope flap can be raised from this incision by intrasulcular extension around one (or more) contiguous tooth, without the need for vertical incisions which would compromise the flap's vascularity and make closure more difficult. If the access of advancement is greater, one or two vertical releasing incisions are added to the horizontal incisions to create a triangular (one release) or trapezoidal (two releases) flap [15]. Incisions are placed away from critical structures and in the aesthetic zone, incisions are placed away from the gingival margins of the visible teeth, to prevent scaring and gingival recession. These designs are compared in Table 3.2.

With aesthetic anterior maxilla, the design of the incision comes second to the preservation of the interdental papillae and the buccal soft-tissue contour. To ensure the final appearance of the implant, peri-implant architecture must be preserved by papilla-sparing incisions and careful management of the buccal tissues [16]. If several implants are to be installed side by side, the distance between the implant needs to be sufficient to preserve inter-implant bone and papilla, as a distance of about 3mm has been recommended to prevent crestal bone loss between implants.

Table 3.2: Comparison of flap and incision designs

Design	Description	Advantages	Considerations
Envelope (crestal only)	Mid-crestal incision with intrasulcular extension; no vertical release.	Preserves vascularity; simple closure; less scarring.	Limited access and advancement.
Triangular (one release)	Crestal incision plus one vertical releasing incision.	Improved access; moderate advancement.	One incision line to heal.
Trapezoidal (two releases)	Crestal incision plus two vertical releasing incisions.	Maximum access and coronal advancement.	Greater tissue trauma; more scarring potential.
Papilla-sparing	Incision designed to leave interdental papillae intact.	Protects aesthetic soft-tissue architecture.	Technically demanding; anterior use.
Flapless (punch)	Circular excision of mucosa over the crest; no reflection.	Minimal trauma; less swelling; faster healing.	Blind preparation; requires adequate bone and guidance.

Design selection balances access, vascularity, closure, and aesthetics for the individual site.

Flapless Surgery

In selected cases, the implant can be placed without creating a flap and by removing a small circular disc of mucosa over the crest and creating the osteotomy through the opening [17]. This is because the periosteum is not reflected in the surgical procedure, which means the crestal blood supply remains undisturbed and the surgery is performed without a flap, which has been shown to result in less postoperative swelling and pain, and quicker soft tissue healing [11]. Although these benefits are present, there is a critical drawback: the preparation is done "blind," which requires sufficient bone volume, favorable ridge morphology, and ideally a well-fitted surgical template created from the 3D images [18]. A review of flapless surgery shows that the results are similar to the flap surgery when suitable cases are selected, but that it is more difficult to visualize the implant in the bone and therefore more risky in inappropriate cases.

OSTEOTOMY PREPARATION

The most critical step for the survival of the interfacial bone is the preparation of the implant site (the osteotomy). The goal is to make a channel of exact size, position, and axis

and keep the bone that will end up Osseo integrated viable. This is achieved by a sequence of progressively larger drills used under conditions that minimize mechanical and thermal trauma. The sequential concept is shown in Figure 3.2 [19].

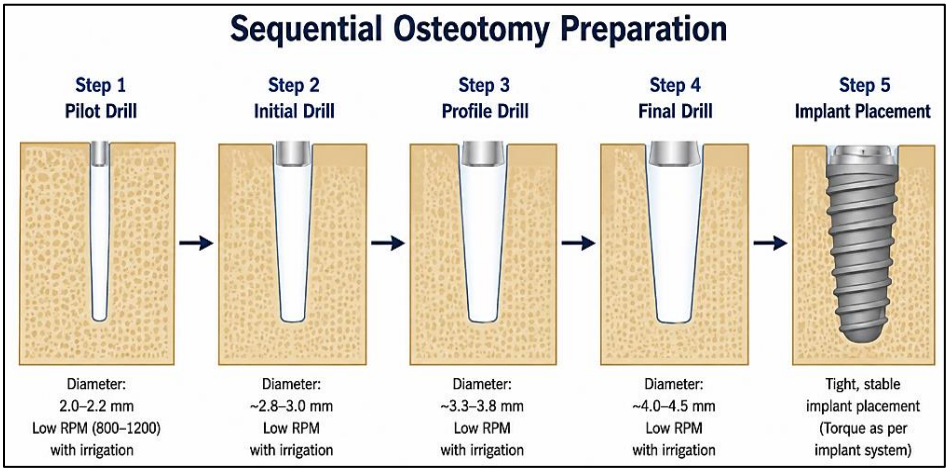

Figure 3.2: Sequential osteotomy preparation. Progressively larger drills widen the site from a pilot channel to a final diameter slightly narrower than the implant, so that the fixture engages bone on insertion. Each drill is used with copious irrigation

Sequential Drilling

The first step in preparation is to mark the location and direction of the entry at the site and on the tooth where it will be determined by the restoration plan (usually with a round bur or a special pilot drill). A narrow pilot drill is then used to set the working depth and the axis of the osteotomy; if the pilot drill is not correct, then the following drills tend to follow. The osteotomy is then expanded in steps with a succession of twist drills of increasing diameter, each twisted to the desired depth. Direction indicators (parallelism pins) are inserted periodically to ensure the axis and on multiple implants to achieve parallelism between sites. A depth gauge is used to check the prepared depth versus the desired implant length before the last drill is used [20].

Two properties of sequential drilling that help preserve the bone. Since only an annulus of bone is being cut, the cutting forces and heat generated are less than if final diameter were attempted in a single passing. Also, the final drill is slightly smaller in diameter than the implant, thus compressing and engaging bone on insertion, creating the primary stability due to the mechanical interlock [21].

Thermal Control

Bone is very temperature sensitive. The classic critical thermal study of Eriksson and Albrektsson showed that approximately 47°C for about one minute above this threshold will cause irreversible damage to the bone, and will lead to the formation of necrotic bone that will not Osseo integrate an implant. During clinical drilling, it was confirmed that the temperatures that can cause such injury can be generated when drilling is not controlled at the osteotomy wall.

Heat generation is controlled by several factors and surgical protocol is driven by control of these factors. The sharpness of the drill is crucial—the heat that is created is significantly greater with a blunt drill. Temperature is also affected by the rotational speed, applied force, and depth of each pass. Most important of all is the copious irrigation with cooled sterile saline to disperse heat generated and to clear bone debris from the flutes of the drill, with external irrigation water directed at the drill, sometimes using the internal water system that can also be used through the drill itself. Irrigant can be brought to the depth of the preparation and it clears debris by withdrawing the drill repeatedly (intermittent drilling). The main parameters of an atraumatic osteotomy are summarized in table 3.3 [22].

Table 3.3: Principles and parameters of atraumatic osteotomy preparation

Parameter	General guidance	Rationale
Drill sequence	Progressive, incremental increase in diameter.	Limits cutting force and heat at each pass.
Drill condition	Sharp drills; discard after the manufacturer's stated number of uses.	Blunt drills generate excess heat and require greater force.
Rotational speed	Moderate speed as specified by the system (commonly a few hundred to ~1200 rpm for cutting).	Excessive speed increases frictional heat.
Irrigation	Copious cooled sterile saline, external ± internal.	Dissipates heat; clears bone debris.
Drilling motion	Intermittent, light, pumping action; avoid excessive pressure.	Allows coolant to reach depth; limits heat build-up.
Final drill size	Slightly narrower than the implant, adjusted to bone density.	Provides mechanical interlock and primary stability.

The osteotomy procedure is adjusted depending on the density of the recipient bone. In dense cortical bone (Lekholm–Zarb type 1 / Misch D1), the entire drilling procedure is performed (sometimes even the coronal threads are countersunk and/or tapped) to prevent excess insertion torque and the potential for compressive bone necrosis. In contrast, the sequence in soft low-density bone (type 4 / D4) is sometimes intentionally under-prepared allowing a narrower final osteotomy and thus increasing the primary stability of the implant [23]. In very soft bone osteotome techniques are sometimes used for the same purpose, whereby the bone is compacted without being removed. Over the compression of bone at the implant site, especially at the implant neck, is not benign: The vascular and remodeling capacity of the surrounding tissue will not keep up with the considerable insertion torque, resulting in localized necrosis often causing an early crestal bone loss.

THREE-DIMENSIONAL IMPLANT POSITIONING

Three-dimensional placement of the implant is as significant as achieving implant integration; a well-integrated implant in the wrong position can be difficult, if not impossible, to restore to a satisfactory position and can be detrimental to the tissues around the implant [24]. Position in the mesio-distal, orofacial (bucco-lingual), apico-coronal planes and angulation of the long axis. The important relationships are shown in Figure 3.3.

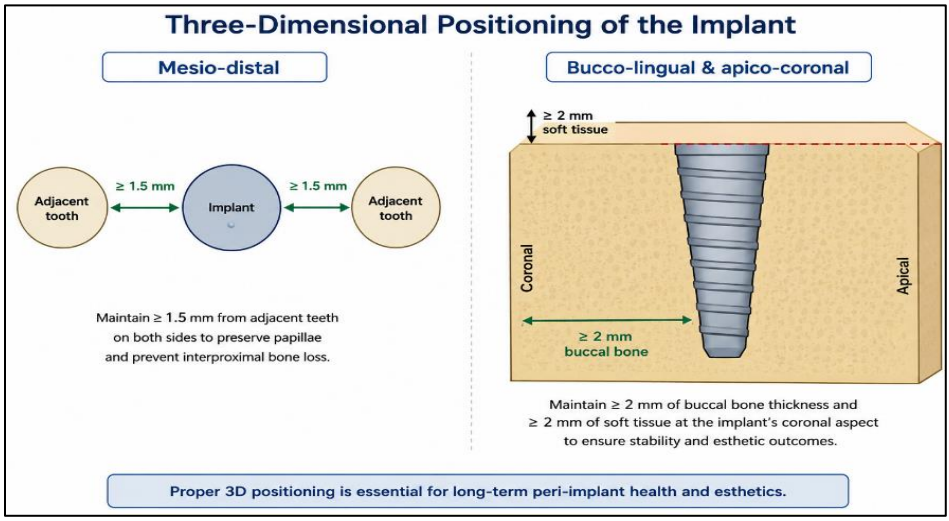

Figure 3.3: Three-dimensional positioning. Mesio-distally, the implant is kept at least ~1.5 mm from adjacent teeth (and ~3 mm from adjacent implants). Orofacially, an intact buccal plate (ideally ≥2 mm) is preserved. Apico-coronally, the platform is placed at an appropriate depth relative to the future restoration

The mesio-distal dimension allows to center the implant in the edentulous space and to keep it clear from the roots of other teeth, with a clearance of at least approximately 1.5 mm from other teeth and approximately 3 mm between implants which helps preserve the inter-proximal bone and papilla. For the orofacial dimension, the implant is oriented so as to leave an unimpaired and, hopefully, sufficient buccal bony wall; a thin or lacking buccal wall is at high risk for bone resorption and is a frequent cause of both aesthetic and biological success failure [25]. The depth of the implant platform is selected based on the planned restoration and the soft tissue level, but not so great as to create excessive pockets or mask the restorative margin in the apico-coronal dimension. Throughout, the long axis is oriented so that occlusal load will be transmitted favorably and the restoration can be retained in a biomechanically and aesthetically sound way.

PRIMARY STABILITY

One of the most significant factors influencing successful osseointegration is primary stability, which is the mechanical stability of the implant immediately after placement: the greater the movement at the interface at the time of healing, the more resources will be invested in developing fibrous capsules rather than bone. Primary stability is provided during surgery whereas secondary stability occurs biologically as bone develops and remodels around the implant [26].

Secondary Stability

The three groups of factors that are responsible for primary stability are the quality and quantity of the recipient bone, the design of the implant and the surgical preparation of the site [27]. More dense bone and more engaged cortical bone results in more fixation; the macro-geometries of the implant such as taper and thread design convert the process of insertion into the process of mechanical interlock; and the size of the final osteotomy versus the size of the implant (degree of under-preparation) modulates the compressive engagement. These determinants are summarized in Table 3.4. Surgeon's influence on primary stability is primarily related to the type of implant utilized and the preparation of the implant site, and secondarily related to the type of implant length and diameter selected.

Table 3.4: Factors affecting primary stability of dental implants

In the mesio-distal dimension, the implant is centered within the edentulous space and kept away Category	**Factor**	**Effect on primary stability**
Recipient bone	Bone density / quality.	Denser bone provides greater mechanical fixation.

Table 3.4 Continued…		
Recipient bone	Cortical engagement.	Engaging cortical bone increases stability.
Implant design	Body form (tapered vs parallel).	Tapered bodies enhance stability, especially in soft bone.
Implant design	Thread depth, pitch, and shape.	Aggressive threads increase interlock and insertion torque.
Implant design	Length and diameter.	Greater dimensions generally increase contact and fixation.
Surgical technique	Osteotomy dimension (under-preparation).	A narrower osteotomy increases compressive engagement.
Surgical technique	Countersinking / tapping in dense bone.	Reduces excessive torque and compression necrosis.

Adapted from studies of implant stability; factors act in combination.

Assessment of Primary Stability

Primary stability may be both clinically and instrumentally assessed. The easiest is by measuring the insertion torque as the implant is seated using a calibrated torque wrench or the surgical motor itself, which is usually sought to be as high as possible — and as low as possible, if immediate loading or restoration is considered — to reflect the increased level of mechanical engagement between the implant and the bone [28]. A non-invasive alternative is resonance frequency analysis (RFA) which measures the resonance of a transducer attached to an implant and calculates stability as an implant stability quotient (ISQ) on a scale from 1 to 100; RFA can be repeated over time to watch the process of changing from primary to secondary stability during healing.

The significance of primary stability is greatest when the conventional undisturbed healing period is shortened. Importance of primary stability has been stressed in reviews of immediate loading, as it is important to have initial stability before the implant can be set in immediate or early function, which is exactly what it does in the initial period before the biological fixation is established. There are a few studies that have published results relating better single-tooth and immediate implant survival with higher insertion torque. Meanwhile, primary stability, which is adequate rather than maximal, based on the plan for the biological and prosthetic, is the goal in dense bone, because too much torque can lead to compression necrosis mentioned above. If the recipient bone is poor quality, the surgeon can make up for this by under-preparing the graft, by choosing a different implant, or by opting for a longer healing time. Once the implant is in place, the surgeon will have to

determine how the implant will heal in relation to the oral environment. The classic two-stage (submerged) protocol involves suturing a cover screw onto the implant and a second minor surgical procedure at a later time to uncover the implant and connect a healing abutment (discussed in Chapter 5), which is not exposed and unloaded during healing. In the single-stage (non-submerged) protocol, a healing abutment or the mucosa penetrating part of a one-piece implant is extended through the mucosa from the beginning, with no second surgery required to uncover the implant, which will heal with a part visible in the mouth [29].

Comparative studies have revealed that both methods have equally high and successful results. Clinical and radiographic results of a 5-year follow-up study of submerged and non-submerged titanium implants were comparable and shortened healing protocols have been shown to predictably integrate on new-generation rough surfaced implants. A Cochrane review of one versus two stage placements found no clear evidence to suggest that either technique is generally superior and the decision is likely to be best made according to the clinical situation and operator preference.

The enrollment is therefore made on a case-by-case basis. A submerged treatment may also be more preferred in the following scenarios: poor primary implant stability, simultaneous bone grafting necessitating protected undisturbed healing or soft-tissue management favoring a buried fixture [30]. In a non-submerged approach, no second surgical procedure is required, treatment is easier for the patient, and it is suitable for the sites that have good bone and do not require grafting. A comparison of the two protocols is in Table 3.5.

Table 3.5: Single-stage versus two-stage protocols

Feature	**Single-stage (non-submerged)**	**Two-stage (submerged)**
Healing configuration	Healing abutment protrudes through the mucosa.	Cover screw; implant buried beneath the mucosa.
Second surgery	Not required for uncovering.	Required to uncover and place a healing abutment.
Advantages	Fewer procedures; simpler for the patient.	Protected, undisturbed healing; useful with grafting.
Preferred when	Good bone and primary stability; no grafting.	Suboptimal stability; simultaneous grafting; soft-tissue needs.
Outcome evidence	High success; comparable to submerged.	High success; long-established.

Both protocols are well documented; selection is guided by the individual case.

IMMEDIATE, EARLY, AND DELAYED PLACEMENT

If the implant is to be placed into an extracted tooth or a tooth that is still present, the question of when to place the implant (simultaneously or sequentially) also arises. The options lie on a spectrum and an internationally agreed-upon classification based on the state of socket healing at placement time classifies four groups based on the healing status. These are set out in Table 3.6.

Table 3.6: Classification of implant placement timing after tooth extraction

Type	Term	Timing after extraction	Status of the socket
Type 1	Immediate	Same appointment as extraction.	Fresh socket; no healing.
Type 2	Early (soft-tissue healing)	Typically, 4–8 weeks.	Soft-tissue healed; minimal bone healing.
Type 3	Early (partial bone healing)	Typically, 12–16 weeks.	Substantial soft-tissue and partial bone healing.
Type 4	Late / delayed	Six months or more.	Fully healed, mature ridge.

After the consensus classification of Hammerle and colleagues; time-frames are approximate.

Each option represents a different balance of benefits and risks. Immediate (Type 1) placement reduces the number of surgical episodes and the overall treatment time and may help preserve tissue contour, but it is technically demanding: primary stability must be obtained in the apical and palatal bone beyond the socket, the gap between implant and socket walls may require grafting, and the aesthetic result in the anterior maxilla is less predictable because it cannot prevent the dimensional remodeling of the socket walls.

The basis of the early and delayed relates to the biology of the healing extraction socket. After tooth extraction, the alveolar ridge changes significantly, and experimental and clinical research have demonstrated significant bundle bone resorption and reduction in width and height of the alveolar ridge, especially in the first few months after extraction, particularly buccally. The placement of the implant after soft-tissues healing (Type 2) ensures a band of keratinized tissue for flap management and permits the resolution of any acute infection, but also guarantees that the implant is placed prior to the complete remodeling of the ridge [31]. The most predictability in terms of bone volume and stability comes with delayed placement into a healed ridge (Type 4), but with the highest resorption and longest treatment time. Modern advice takes the decision as a compromise, which can be adjusted to the site, the state of the walls of the sockets, the cosmetics, and the experience of the operator.

SUMMARY AND CLINICAL PERSPECTIVE

The surgical placement of an implant is a sequence of interdependent maneuvers, each of which serves the single biological goal of osseointegration. Contamination is controlled by a clean technique built around sterile instrumentation and a protected field [3]; access is obtained through a flap designed to balance visibility against the preservation of vascularity and aesthetics the osteotomy is cut a traumatically, above all by avoiding the thermal injury that follows uncontrolled drilling; and the implant is seated in a correct three-dimensional position with primary stability sufficient to control micromotion during healing.

Around this core sequence lie two families of decisions. The first concerns the healing configuration whether to submerge the implant in a two-stage protocol or to leave a component transmucosal in a single-stage protocol a choice that the evidence shows can be made on clinical grounds without prejudice to success. The second concerns the timing of placement relative to extraction, ranging from immediate placement into a fresh socket to delayed placement into a fully healed ridge, each with a characteristic balance of convenience, tissue preservation, and predictability.

Mastery of these fundamental maneuvers is the foundation of implant surgery. The soft- and hard-tissue management techniques of Chapter 4 extend them to the compromised sites that these basic protocols alone cannot address, and the prosthetic phase of Chapter 5 builds upon the position and stability established here. A surgeon who places implants gently, precisely, and in the right place, while respecting the biology of the bone at every step, gives each fixture the best possible opportunity to integrate and to serve the patient for the long term.

❑❑❑

CHAPTER 4

SOFT AND HARD TISSUE MANAGEMENT

Suturing • Socket Preservation • Bone Grafting • Guided Bone Regeneration • Sinus Augmentation Soft-Tissue Handling

INTRODUCTION

The implant will only be integrated if there is enough viable bone present around it and a good soft-tissue envelope around it that is well vascularized, and therefore stable. If either is missing, the clinician will have to fill in the missing piece. Technique varies from simple (well placed suture or graft in a new socket) to technically challenging (guided bone regeneration – large defect or elevation of the maxillary sinus floor). They form the reconstructive base on which successful and predictable implant therapy of compromised sites is based [1].

The chapter has two themes. The second is that hard- and soft-tissue management cannot be separated: bone regeneration relies on soft-tissue overlying it that is tension-free and non-dehiscing, and the long-term success of the soft tissue relies on the support of the underlying bone. The second is that all of these procedures adhere to the same biological principles of healing wounds as does osseointegration — an undisturbed clot, adequate blood supply, protected space, and mechanical stability. The exercises mentioned in this article can be best understood as steps taken to set up and maintain the conditions for the body's own healing to take place.

The principles of wound healing and tissue handling will be explained. The principles of wound healing and tissue handling will be explained. he success of regeneration is dependent on a few biological factors which can be usefully summarized by the mnemonic PASS: primary wound closure, angiogenesis, space maintenance, stability of the wound and graft [2]. Primary closure protects the healing site from the oral environment, a rich blood supply (angiogenesis) brings the cells and factors needed to create new tissue, the maintenance of space allows the bone to grow into the new space, and mechanical stability of the clot, graft, and any implant prevents micromotion that will obstruct the healing tissue's ability to shift its path towards fibrous repair. All grafting and membrane methods in this chapter can be judged on the basis of the four following conditions.

These principles are manifested in tissue handling practice. Flaps should have a wide base to maintain perfusion, as far as is necessary, should be kept moist and handled with fine instruments to prevent crushing. When closure, the wound edge should close passively,

otherwise, tension will cause disruption of the margin's blood supply and will be a major factor in wound dehiscence and subsequent exposure of grafts or membranes [3]. The issues raised in Chapter 3 for routine flaps assume increased importance when a graft can't be uncovered or disturbed for months. The process of wound healing occurs in stages. Wound healing is a process that occurs in stages. There are a series of stages in the healing process that all soft tissue and bony wounds go through, and understanding the time course of these stages will help to explain why grafted areas must be guarded for long periods of time. The first stage, called hemostasis, involves the formation and stabilization of a blood clot that seals the wound in minutes to hours [4]. Then it goes through an inflammatory phase in the first few days which involves neutrophils and macrophages cleaning up the wound and secreting the molecules that attract the repair cells. During the next days and weeks in the proliferative phase, new blood vessels invade the wound (angiogenesis), the fibroblasts deposit a provisional matrix and in bone osteogenic cells start to deposit woven bone. Lastly, a long remodeling period, which can take months, transforms provisional tissue into organized, load bearing bone and stable connective tissue [5]. The clinical implication is that during the early tissue formation in the proliferative phase, the tissue is sensitive, both mechanically and biologically, and needs to be protected from micromotion, infection and premature loading until it has been made stronger by the remodeling process. This is why barrier membranes must stay in place, grafts must be tied down and healing times for enhanced sites are months instead of weeks. A dehiscence that exposes a graft or membrane in these early stages will disrupt the process, and often result in infection and loss of regenerated volume [6]. The procedure that brings a reflected flap back to a closed, healing wound. They are used to approximate wound margins in the desired position, to keep wound margins in place without tension or excessive compression, to control bleeding and in regenerative surgery to secure primary closure over the graft or membrane. These purposes, and those of the biological and aesthetic requirements at the site, dictate the type of suture material and technique chosen [7].

SUTURE MATERIALS

There are two categories of suture materials: resorbable and non-resorbable, monofilament and multifilament (braided). Resorbable sutures are absorbed and later eliminated by the body over days to weeks, and can be used where it is not possible to remove sutures; non-resorbable sutures will not absorb, they will remain strong indefinitely and should be removed. Monofilament sutures are smooth and do not support bacterial growth, but are more difficult to handle and knotted; braided sutures are easy to handle and have a strong knot, but the holes may be prone to bacterial colonization, especially in the oral environment that is rich in bacteria [8]. The common categories with their characteristics are summarized in Table 4.1.

Table 4.1: Classification and properties of common suture materials

Material	Resorbable?	Filament	Notes
Silk	No	Braided	Excellent handling; braided structure may harbor plaque; historically common.
Polyester / nylon (polyamide)	No	Mono/multi	Strong, low tissue reaction; monofilament resists colonization; requires removal.
e-PTFE	No	Monofilament	Very low plaque affinity; favored for regenerative and aesthetic sites.
Plain/chromic gut	Yes	Monofilament (natural)	Rapid to moderate resorption; more tissue reaction.
Polyglycolic/ polyglactin acid	Yes	Braided (coated)	Predictable resorption; good handling; widely used.
Poliglecaprone/ polydioxanone	Yes	Monofilament	Resorbable with low tissue reaction and smooth passage.

Selection balances resorption, handling, knot security, and plaque affinity for the site.

SUTURING TECHNIQUES

There is several different suturing techniques used in implant surgery each appropriate to a certain scenario. The main patterns are shown in Figure 4.1 and the indications correlated with these patterns are given in Table 4.2.

The simple interrupted suture is the workhorse of oral surgery, with each stitch closing the margins and failure of one stitch not affecting the others. Mattress sutures (horizontal or vertical) involve more tissue to be held, distribute tension and evert or precisely adapt wound margins; they are useful for providing a tight closure and for providing tension-free primary closure over grafts. Useful for positioning papillae and single-sided flaps where compression of tissue against bone is not important, the sling (suspensory) suture suspends a flap. A long wound is rapidly closed with a continuous suture that stretches evenly, but is only one strand. In either method, knots are tied around the side of the incision and not directly over it, so as not to strangle the tissue, and with enough throws for the material to

be used. In either case, the knots are placed to the side of the incision and not directly over it; they are knotted without strangulating the tissue; and they are secured with enough throws for the material to be used [9].

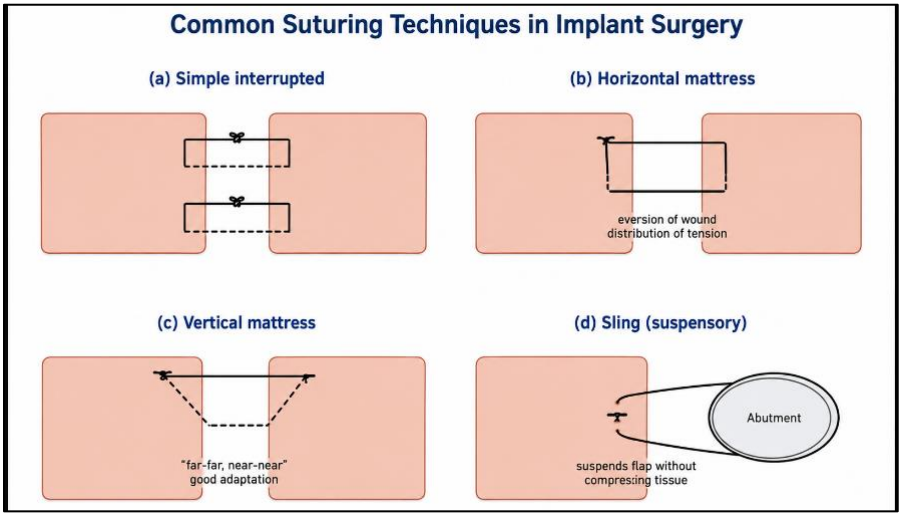

Figure 4.1: Common suturing techniques: (a) simple interrupted; (b) horizontal mattress; (c) vertical mattress; (d) sling (suspensory) suture around an abutment or tooth

Table 4.2: Suturing techniques and their principal indications

Technique	Description	Typical indication
Simple interrupted	Individual independent stitches.	General flap approximation; versatile default.
Horizontal mattress	Two parallel horizontal passes.	Everting margins; broad, tension-distributing closure over grafts.
Vertical mattress	Deep and superficial passes ("far-far, near-near").	Precise margin adaptation; deep tissue apposition.
Sling / suspensory	Suture looped around a tooth or abutment.	Positioning papillae; single-sided flaps; avoids tissue compression.
Continuous (running)	One uninterrupted strand.	Long edentulous spans; even tension; speed.

Techniques are frequently combined within a single closure to meet local needs.

SOCKET AND RIDGE PRESERVATION

Remodeling of the alveolar bone occurs as a predictable sequence which cannot be avoided following tooth extraction. Following extraction, the bundle bone that lines the socket receives some blood supply from the periodontal ligament and the resorption of the buccal wall following extraction of this bone causes the walls of the socket to resorb; this is most pronounced on the thin buccal plate and will result in a fall in the width and height of the residual ridge. Experiments and clinical trials have estimated this alteration: a significant amount of the ridge width can be lost, and a lesser but significant amount of the ridge height. A systematic review of change after extraction showed clinically significant horizontal and vertical reductions in the healing socket [10].

This remodeling can lead to inadequate bone volume or an inappropriate ridge configuration, which can affect subsequent implant placement. To be able to minimize these changes, socket (or alveolar ridge) preservation involves placing a graft material into the socket at the time of tooth extraction, which can be covered with a membrane or soft tissue graft. The meta-analysis of ridge preservation procedures reported that grafting the socket resulted in only a small amount of horizontal and vertical dimensional loss, but not enough to rule it out [9]. Therefore, consensus reviews suggest that the preservation of the ridge contour be taken into consideration in the event of damaged socket walls, when implant placement will be postponed or when it is important to preserve the ridge contour for the esthetic outcome [11].

The concept is very simple: The tooth is removed a traumatically in order to leave the walls of the tooth socket intact, the socket is debrided of granulation tissue, a graft material is placed in the socket to fill the defect and to maintain the space, and the tooth socket is protected (with a membrane, with a soft-tissue graft, or together) and closed as much as possible. There is a need to understand that ridge preservation cannot prevent resorption, but can only delay it, and that ridge preservation will not regenerate bone that has already been lost – it is designed to maintain existing bone at the time of extraction [12].

The very basis of the procedure is atraumatic extraction; such is a fine buccal plate, that it can very easily be broken by careless use of elevators and forceps, and the loss of this plate compromises the procedure itself. The walls are spared by the use of periotomes and fine luxators and by sectioning multi-rooted teeth [13]. The integrity of the buccal wall after extraction is also an important factor to consider: A buccal wall that remains intact is well contained and heals predictably with a particulate graft; a buccal wall with a damaged or absent wall behaves as a noncontained defect and may require the more involved reconstructive measures described later in this chapter [14]. The clinician also considers whether to preserve or place an implant immediately, as discussed in Chapter 3, as both approaches are confronting the same biological issue (post-extraction remodeling), but doing so in two different ways.

BONE GRAFTING MATERIALS AND BIOLOGY

Bone grafting is at the heart of reconstructive implant surgery, be that to save a socket, build-up a deficient ridge, or fill a sinus. Graft materials are known to act by three different biological mechanisms to promote new bone. Osteogenesis, recruitment and stimulation of the host's own progenitor cells to differentiate into bone-forming cells (osteoinduction); and providing a passive scaffold along which host bone will grow (osteoconduction). These mechanisms can all operate in the same material [15].

Graft materials are divided into two categories, based on their source. The drawbacks to autografts (from the patient) include a second surgical site, associated morbidity, limited availability, and resorption [16]. Allografts (from a human donor, processed and sterilized) and xenografts (from another species, typically bovine or porcine, deproteinized to leave a mineral scaffold) do not require a donor site, and are widely used, especially the latter which have a slow resorption rate and thus a long-lasting effect on volume. Alloplasts are synthetic materials which are osteoconductive, like calcium phosphates, bioactive glasses, etc. [17]. These categories are compared in Table 4.3.

Table 4.3: Classification of bone graft materials

Type	Source	Mechanism(s)	Notes
Autograft	The patient's own bone.	Osteogenic, osteoinductive, osteoconductive.	Gold standard; donor-site morbidity; may resorb.
Allograft	Human donor (e.g. FDBA / DFDBA).	Osteoconductive (± osteoinductive).	No donor site; processed and screened.
Xenograft	Another species (e.g. bovine).	Osteoconductive.	Slow resorption; good volume maintenance.
Alloplast	Synthetic (e.g. calcium phosphate, bioactive glass).	Osteoconductive.	Unlimited supply; variable resorption.

FDBA: freeze-dried bone allograft; DFDBA: demineralized freeze-dried bone allograft.

In practice, however, it is sometimes necessary to use combinations of materials to harness complementary properties, such as using a slowly resorbing xenograft for space and volume maintenance, and autogeneous bone for its osteogenic and osteoinductive properties. Selection of material is dependent on the size and shape of the defect, whether the defect walls can be contained, whether it is necessary for the material to be stable in volume over time, and the clinician's assessment of the relative balance of the biological performance and surgical morbidity [18].

The Defect Morphology and Graft Containment

The predictability of any grafting procedure is greatly dependent on the morphology of the defect and, in particular, the number of bony walls surrounding and containing the defect. A space that is well contained, like an extraction socket or a defect limited by a few bony walls, has its own space maintenance and blood supply and has a more predictable healing result; in this case, only a simple membrane and a particulate graft should be used. A poorly contained defect, like a horizontal or vertical ridge defect with few surrounding walls, will require more from the reconstruction, including rigid space maintenance, secure graft and membrane fixation, and often will require a staged approach. Therefore, an early determination of the type of defect is important in choosing a suitable technique and in assessing the chances of success [19].

Biologic Adjuncts

In addition to the graft materials, a variety of biologic adjuncts helps stimulate the regeneration response. Autogenous platelet concentrates are produced by centrifuging a small volume of the patient's own blood, providing a concentrated supply of platelets and the growth factors they secrete, as well as a fibrin matrix which can help platelet handling and wound healing. Other bioactive molecule such as recombinant growth factors has also been tested for their ability to augment osteoinduction. These are typically applied in addition to traditional grafting and there is mixed evidence of efficacy depending on the use; the role of these is still being refined [20]. They should be considered as additions to a good grafting technique, not as the replacement of basic biological and mechanical principles which influence the success of the treatment.

GUIDED BONE REGENERATION

Guided bone regeneration in the jaws is the use of the principle of guided tissue regeneration: a barrier membrane is applied on the top of a defect area that excludes the rapidly growing soft-tissue cells (epithelia and connective tissue cells), which leaves a protected space to allow for the regeneration of the area by the slower-growing cells that form bone. The idea was first tested by Dahlin and his colleagues who demonstrated healing of defects covered with a membrane by bone, while unprotected defects were filled with fibrous tissue [21] and was quickly translated into clinical implant use to treat dehiscence’s, fenestrations and localized ridge defects [22]. The principle is demonstrated in Figure 4.2.

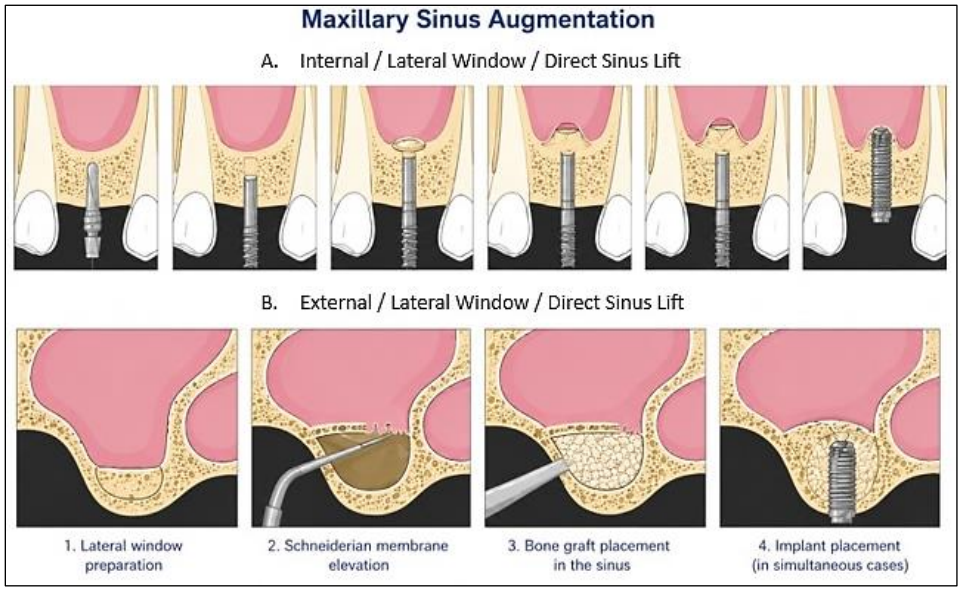

Figure 4.2: The principle of guided bone regeneration. A bony defect exposing implant threads (1) is filled with graft and covered by a barrier membrane (2), which excludes soft-tissue cells and maintains space so that bone regenerates to cover the implant (3).

Biological Basis and the Role of Membranes

The regenerative outcome of GBR depends on the same conditions summarized by the PASS principles: the membrane must be covered by a tension-free primary closure, the site must be well vascularized, the space beneath the membrane must be maintained (usually by a supporting graft), and the membrane, graft, and any implant must be stable during healing [23]. The membrane performs two functions cell occlusion and space maintenance — and its ability to maintain space depends on its stiffness and on the support provided by the underlying graft. A membrane that collapses into the defect forfeits the volume it was intended to protect. Contemporary reviews emphasize that GBR is not merely a mechanical barrier effect but an orchestrated biological process in which the membrane also modulates the local healing environment.

Barrier Membranes

Barrier membranes are broadly divided into non-resorbable and resorbable types. Non-resorbable membranes historically expanded polytetrafluoroethylene (e-PTFE), often reinforced with titanium for rigidity, and titanium mesh provide excellent space

maintenance and are suited to larger, non-contained defects, but they require a second procedure for removal and are prone to complications if exposed to the oral cavity. Resorbable membranes principally collagen, and various synthetic polymers are eliminated by the body, avoiding a removal procedure and tolerating exposure more gracefully, but they offer less rigid space maintenance and a shorter and less predictable barrier duration. Table 4.4 contrasts the two classes [24].

Table 4.4: Barrier membranes for guided bone regeneration

Property	**Non-resorbable (e.g. e-PTFE, Timesh)**	**Resorbable (e.g. collagen)**
Space maintenance	Excellent, especially titanium-reinforced.	Limited; relies on graft support.
Removal surgery	Required.	Not required.
Handling	Stiffer; may need fixation.	Conformable; easy to adapt.
Exposure behavior	Exposure often leads to infection.	Better tolerated if exposed.
Best suited to	Large / non-contained defects.	Smaller / contained defects (e.g. dehiscence).

Membrane choice is dictated by defect size, containment, and the need for rigid space maintenance.

Simultaneous versus Staged Augmentation

The connection of the GBR can be done at the time of the implant placement (simultaneous approach) or as an earlier surgical procedure to create the ridge prior to implant placement (staged approach). When the residual bone offers good primary stability and the defect is favorable (such as a dehiscence or fenestration around otherwise stable implant) and would shorten the treatment time and the number of surgical interventions, then the simultaneous approach can be implemented. The staged approach is used for larger deficiencies, in which the implant may not be placed in a proper position with enough stability in the beginning. Systematic reviews indicate that the technique of GBR provides high implant survival after treatment of peri-implant defects and when cases are selected and performed properly, the technique is predictable [21].

Complications and Their Management

The most frequent and serious problem associated with GBR is exposure of the membrane by the overlying soft tissue (dehiscence). Exposure can lead to bacterial contamination of the membrane and graft as well as often to infection and a decrease in regenerated bone with non-resorbable membranes. All measures that influence all regenerative surgery also reduce the risk of exposure: tension-free primary closure through adequate flap release,

atraumatic handling of the tissues and prevention of pressure of the provisional prostheses during healing [4]. The management of exposure depends on the type of membrane involved (whether resorbable or non-resorbable) and includes careful local hygiene and observation in case of minimal exposure to non-resorbable in case of exposure, early removal to prevent progressive infection in the case of non-resorbable. The best approach for preventing wildfires is to design and close flaps correctly, rather than to manage them [22].

Maxillary Sinus Considerations

The placement of implants in the posterior maxilla is a special challenge. Maxillary molars and pre-molars are lost and the remaining ridge resorbs from the top and the maxillary sinus pneumatizes from the bottom, which means there is often very little vertical dimension between the alveolar crest and the sinus floor to support a conventional implant. The density of the bone of the area is also frequently low. If the sinus (Schneiderian) membrane is missing, the area can be regenerated using a procedure called maxillary sinus floor augmentation, or sinus lift [23].

This technique has been introduced by pioneering work of Boyne and James in sinus grafting through the lateral window [24] and the work of Tatum in implant reconstruction with sinus augmentation. A less invasive transcrestal approach using osteotomes described by Summers was then described.

The Lateral Window (Direct) Approach

Lateral-window technique is a technique where a window is surgically created in the lateral wall of the sinus, the Schneiderian membrane is gently lifted from the sinus floor and walls, and the space beneath the lifted membrane is filled with the graft material. Some implants can be inserted at the same time if there is enough remaining bone to support the implants, or they can be inserted at a later time when the graft has hardened. The direct approach allows for large graft volume, is done under vision and is appropriate for significant deficiencies. The major intra-operative complication is the perforation of the Schneiderian membrane that should be identified and corrected [25].

Transcrestal (Osteotome) Approach

The transcrestal technique raises up the sinus floor via the implant osteotomy. The osteotomy is cut to just below the sinus floor, and osteotomes (or special instruments) gently lift the membrane locally by a few millimeters (usually with the help of some bone graft material) and the implant is then placed. This approach involves less morbidity, is less invasive, and can be used when only a small increase in height is desired and there is

sufficient remaining bone to hold the implant in place [26]. The disadvantages are that it is not as high as it can be and that the membrane is not seen from the ground. A comparison of the two approaches is given in Table 4.5.

Table 4.5: Comparison of maxillary sinus augmentation approaches

Feature	Lateral window (direct)	Transcrestal (osteotome)
Access	Osteotomy in the lateral sinus wall.	Through the implant osteotomy from the crest.
Feature	Lateral window (direct)	Transcrestal (osteotome)
Elevation achievable	Large; suitable for severe deficiency.	Limited (a few millimetres).
Residualbone needed	Can be minimal (staged option).	Adequate to stabilize the implant.
Invasiveness/ morbidity	Greater.	Less.
Visualization	Direct.	Indirect (blind elevation).
Main complication	Membrane perforation.	Membrane perforation; limited control.

Selection depends chiefly on the residual bone height and the elevation required.

This decision on which approach to take is determined primarily by the amount of bone remaining beneath the sinus and by the height needed. Based on the above, it may be concluded that sites with adequate residual height (RH) that require only a small vertical augmentation are best treated with simultaneous implant placement in the transcrestal approach, whereas sites with significantly reduced RH or those that require significant vertical augmentation are more likely to be treated with the lateral window, staged approach with no primary stability. Sinus pathology is also evaluated pre-operatively: whether it is acute or chronic sinus disease, the thickness of the sinus membrane or if the ostium is obstructed may preclude the elevation until the sinus is assessed and treated if needed. A comprehensive radiographic evaluation (preferably computed tomography (CT) using cone beam as mentioned in Chapter 2) is therefore a prerequisite [27].

The two methods are well established and when used appropriately result in good implant survival rates. Systematic review of SFE outcomes has shown survival of SFE implants to be similar to those in native bone when a competent surgeon performs the procedure and complications are addressed [28]. In both techniques, the most common complication is perforation of the Schneiderian membrane, which can be easily repaired with a collagen membrane if it is small, or may require the procedure to be repeated after

healing, if it is large. The specific technique and material used is customized to the anatomical and deficiency issues, like in all grafting. The doctor will then perform soft tissue management around the implant(s). The soft tissue that envelops an implant isn't just a cosmetic element; it creates the biological seal that shields the underlying bone from the oral environment. The peri-implant mucosa creates a dimension of epithelial and connective-tissue attachment which is similar to the biological width around natural teeth. Berglundh and Lindhe showed that the underlying bone will resorb into the mucosa when the thickness and height of the mucosa is insufficient, making it clear that adequate soft-tissue thickness and height are critical to obtaining a stable result [29].

Keratinised Mucosa

Healthy peri-implant tissue around an implant has been associated with a band of firm, keratinized (attached) mucosa, which is believed to be beneficial for plaque control and for avoiding recession and inflammation from mobile, non-keratinized mucosa. A systematic review reported a correlation between a decreased width of keratinized mucosa and increased amount of plaque, inflammation, and soft-tissue recession, with a less clear correlation to implant survival [30]. When keratinized tissue is lacking, it may be increased surgically, most obviously with a free gingival graft.

Soft-Tissue Grafting Procedures

The peri-implant soft tissue augmentation is performed with two classical grafting techniques that come from periodontal plastic surgery. The free gingival graft (FGG) which is a graft of keratinized epithelium and connective tissue taken (usually from the palate) and grafted onto a recipient bed, is the most commonly used to augment the width of keratinized mucosa [31]. The subepithelial connective-tissue graft (CTG) is the one that is most commonly utilized to augment soft-tissue thickness and volume and to enhance aesthetics: the superficial connective tissue surface remains intact over the recipient tissue. A systematic review showed that soft-tissue augmentation may be an effective method to widen the keratinized tissue and increase the thickness of the mucous lining around implants [32]. A comparison of the two procedures is given in Table 4.6.

Table 4.6: Soft-tissue grafting procedures around implants

Feature	Free gingival graft (FGG)	Connective-tissue graft (CTG)
Graft composition	Epithelium + connective tissue.	Subepithelial connective tissue only.
Primary purpose	Increase width of keratinized mucosa.	Increase soft-tissue thickness / volume.

Table 4.6 Continued…		
Coverage	Graft left exposed on the recipient bed.	Graft placed beneath a covering flap.
Aesthetics	Color/texture may differ from adjacent tissue.	Superior blending; preferred in aesthetic zone.
Typical indication	Deficient keratinized tissue band.	Thin biotype; contour and aesthetic deficiency.

The two grafts are complementary; the choice follows the tissue deficiency to be corrected.

They will be able to describe the Peri-implant Papilla and the Emergence Profile.

The soft tissue outcome in the aesthetic zone is dependent not only on the amount of mucosa, the keratinization of the mucosa, but also on the presence of interdental papillae and on a natural emergence profile of the mucosa and restoration. The bone crest level of the neighboring tooth determines the presence of a papilla between an implant and adjacent tooth, while the level of the inter-implant bone determines the presence of a papilla between two neighboring implants, one of the reasons why adequate inter-implant spacing (discussed in Chapter 3) is so important. During the prosthetic phase, the peri-implant mucosa contour is increasingly sculpted by the healing abutment and provisional restoration that help to create a natural emergence form prior to the definitive restoration [32].

Depending on treatment plan and soft-tissue deficiency, soft-tissue grafting can be done prior to implant placement, at the time of implant placement, at second-stage surgery or after the restoration. Excess soft-tissue volume prior to or at the time of placement is often desirable when the soft tissue is thin and the mucosal margin is likely to be compromised by it; contour refinement can be done later in the prosthetic stage. The careful, calibrated handling and creation of a well vascularized recipient bed as in the case of bone grafting are the key factors in achieving a successful, stable result [33].

SUMMARY AND CLINICAL PERSPECTIVE

Tissue management is what allows implant therapy to extend beyond the ideal, well-endowed site to the compromised ridges that predominate in clinical practice. The procedures described in this chapter share a common biological foundation the requirements for wound closure, blood supply, protected space, and stability captured by the PASS principles and a common surgical discipline of gentle, tension-free tissue handling.

Hard-tissue management begins at the moment of extraction, where socket preservation can conserve a ridge that would otherwise resorb, and extends through the grafting of localized defects and the guided regeneration of bone beneath a barrier

membrane to the elevation of the maxillary sinus floor in the deficient posterior maxilla. Soft-tissue management ensures that the reconstructed bone is protected by a stable, keratinized, and where appearance matters aesthetically appropriate mucosal envelope.

❑❑❑

CHAPTER 5

HEALING, SECOND-STAGE SURGERY, AND THE PROSTHETIC PHASE

Healing & Loading • Uncovering • Impressions & Digital Workflows • Abutment Selection • Screw- vs Cement-Retained Restorations

Placing an implant is only half of implant therapy; the other half is converting an integrated fixture into a functioning, comfortable, and durable restoration. This chapter follows that second half of the journey. It begins with the healing period during which osseointegration matures and the loading protocols that determine when the implant may bear function, proceeds through the uncovering of submerged implants and the conditioning of the peri-implant soft tissue, and then addresses the restorative sequence itself: capturing the position of the implant by conventional or digital impression, selecting an abutment, and choosing between a screw-retained and a cement-retained prosthesis. Throughout, the aim is to translate a biologically successful surgery into a clinically successful result.

INTRODUCTION

The implant is only useful to the patient when it's transitioning from surgery to restoration. It relies on other skills from the previous chapters (impression-making, occlusion, materials selection, and an eye for aesthetics) and upon the same biological realities. The restoration should not deconstruct the interface with the osseous tissue, apply excessive forces and be enclosed by soft tissues that will remain clean and healthy for the long-term. New findings from the present day increasingly see these decisions on to, what, when and which ending and impression mode to choose in relation to the specific context and not as a rule [1].

The sequence is listed here in the order that it is executed. The reader should remember that the restoration is not an afterthought: as stated in Chapter 2, the treatment is planned backwards from the planned restoration, and the location of the implant in Chapter 3 determines the entire treatment presented here. The easy part of the restoration is to have a good implant placed; the difficult part is to have a bad implant placed, even a simple restoration is hard or impossible to make [2].

Once the implant is placed, a waiting period permits the osseointegration and maturation. According to the original protocols, the mandible needed approximately 3-4 months of healing while the maxilla needed 6 months for healing to occur, a period of time

that was undisturbed and unloaded, due to the fact that the mandible was more dense and typically healed more quickly than the maxilla [3]. These intervals were deliberately conservative, and were selected to ensure integration prior to any functional loading. These phases can be successfully shortened in many cases and predictable earlier loading protocols are possible due to the advent of modern, moderately rough implant surfaces (Chapter 1) that integrate faster and more strongly.

Loading Protocols

There is a standardized terminology for the timing of loading, that is, when the implant is placed in functional occlusion with a restoration. Conventional loading is the restoration that is placed after a healing duration of two months or more during which the patient has not been subjected to any usage. Early loading is done within 1-2 months of placement. Immediate loading is a restoration that is placed in occlusal function within a week of placement [4]. A related concept, 'immediate restoration' (also called 'previsualization'), ensures that a restoration, which is intentionally not placed in occlusal contact, is not subjected to functional loading within the first week, while allowing the aesthetics and soft-tissue contour to be dealt with without such loading. These definitions are summarized in Figure 5.1 and Table 5.1.

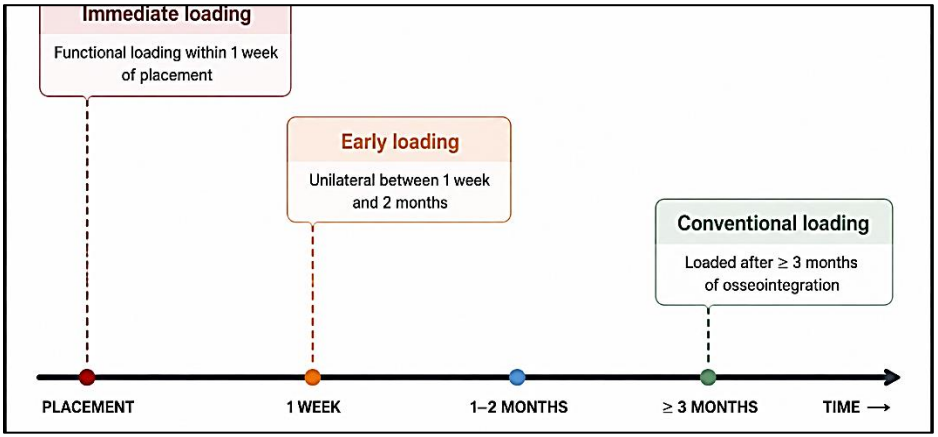

Figure 5.1: The principal implant loading protocols defined by the interval between placement and functional loading. All require adequate primary stability, and the earlier protocols are the more demanding of it

One common factor between all of these protocols is the control of micromotion at the bone-implant interface during healing. Experimental studies showed that micromotion at interfaces greater than approximately 50-150 micrometres will promote fibrous

encapsulation rather than bone formation [5]. Therefore, immediate and early loading are only possible when primary stability is adequate to prevent micromotion from ever exceeding this threshold during function, hence adequate insertion torque or high implant stability quotient is required for immediate and early loadings; and is done so with caution in soft bone. Several consensus reviews and systematic analyses have demonstrated that early and immediate loading can lead to comparable survival rates as conventional loading, given appropriate selection of cases [6] and that the predictability of immediate loading is dependent on the type of restoration and the attainment of primary stability [7].

Table 5.1: Implant loading protocols

Protocol	**Timing of functional loading**	**Principal requirement / comment**
Conventional loading	≥ 2 months after placement.	Undisturbed healing; the most conservative, broadly applicable option.
Early loading	Between 1 week and 2 months.	Requires good primary stability; supported by modern surfaces.
Immediate loading	Within 1 week	Demands high primary stability; case selection
Protocol	Timing of functional loading	Principal requirement / comment
	occlusion).	critical.
Immediate restoration	Within 1 week (out of occlusion).	Addresses aesthetics/contour without functional load.

Terminology after loading-protocol consensus statements; intervals are the commonly used boundaries.

Monitoring Integration

The clinician checks that an implant is integrated before he or she restores it. In the clinic, an integrated implant is a nonmoving, painless functional and percussion implant, and is without peri-implant infection or progressive bone loss. Resonance frequency analysis has been developed to be a non-invasive, repeatable index of stability that can be followed throughout the healing period as primary stability is replaced by secondary stability, and when an objective measure is desired, especially when considering early or immediate loading, or when integration may be in question [8]. An increasing or sustained stability quotient is good news; a decreasing stability quotient is bad news and should be treated with caution.

Sometimes implants do not bond to the bone. Early failure occurs at or soon after the time of discovery and can manifest as mobility of the fixture, discomfort or a radiolucent zone around the fixture, as a result of excessive micromotion, thermal injury during fixture placement, infection, or inadequate host bone. It is not possible to restore a mobile implant and it should be removed; the site can then be re-evaluated after some healing and, if appropriate, another implant inserted. When the implant fails, it is important to differentiate it from one that is healing slowly, and this can be done by the clinical assessment and, if available, stability measurement and radiographs. The incidence of early failures is rare with good technique and should make the surgeon think about factors that could have played a role (surgical, biological and prosthetic) [9].

SECOND-STAGE (UNCOVERING) SURGERY

Under a two-stage (submerged) protocol, described in Chapter 3, the implants are covered with mucosa during healing and are uncovered in surgery for restoration. This second stage procedure involves exposing the implant, removing the cover screw, and placing a healing abutment which extends through the mucosa and creates the transmucosal pathway for a restoration. Single stage (non-submerged) implants do not need this step as they have a transmucosal component [10].

Techniques for Uncovering

There are a number of techniques to consider, depending on the quantity and location of the keratinized tissue and the requirements of the area to be treated in terms of aesthetics. Where there is a lot of keratinized tissue and this is not an aesthetic concern, the easiest way to do this is with a tissue punch which excises a small circular disc of mucosa over the cover screw, with minimal trauma and no flap creating the healing abutment and allowing the abutment to be connected easily. If the tissue needs to be preserved or repositioned, a small flap is elevated (either a crestal or slightly palatal incision): the keratinized tissue can be conserved and, if needed, an apically positioned flap can be employed to widen the keratinized mucosa on the buccal side of the implant. In the aesthetic zone, uncovering can be performed in conjunction with soft-tissue grafting or in conjunction with techniques that create the interdental papillae, so that the second stage surgery is an opportunity to improve the soft tissue architecture of the peri-implant area, instead of only for uncovering [11].

In either case, the cover screw will be removed and the internal surface of the implant examined and cleaned, and a healing abutment of proper diameter and height will be attached. The height chosen to ensure the abutment pierce through and protrude above the mucosa, and the diameter for the emergence profile of the future restoration. The soft tissue is then allowed to heal and adapt around the healing abutment for days to weeks until impressions are taken.

Healing of the Healing Abutment and Transmucosal Healing

The healing abutment (or healing cap) does not only keep the implant accessible, it sets up and maintains the transmucosal channel and starts to create the soft tissue seal around the implant. In this time of transmucosal healing a layer of epithelial and connective tissue attaches to the surface of the abutment and restores the protective barrier between the oral environment and the underlying bone. One of the most important things to consider is the choice of a healing abutment that is an appropriate height—too short will lead to mucosa overgrowing it while a healing abutment that supports tissue at the proper height will make later restorative procedures much easier. The healing abutment is followed by an emergence contour that is developed by the provisional and definitive restoration, which is discussed in the next section. Undisturbed transmucosal healing for 1 to a few weeks prior to manipulation of the peri-implant mucosa for impressions will improve the accuracy of the impressions and the stability of the final soft-tissue margin [12].

PROVISIONALIZATION AND SOFT-TISSUE CONDITIONING

Not only is the soft tissue surrounding a healing abutment or a provisional restoration passive, it can also be sculpted to create a natural, cleanable and esthetic emergence of a final restoration from the mucosa. This is especially true for the aesthetic zone, in which the look of the restoration is not just determined by the crown, but also by the soft tissue around it [13].

The shape of the restoration as it passes through the mucosa can be characterized by a critical contour (the area immediately apical to the mucosal margin that has the greatest impact on the position and shape of the mucosal margin) and a subcritical contour (apical to the critical contour that affects the fullness of the tissue). These contours can be modified on a provisional restoration to direct the mucosa margin coronally or apically and to form the emergence profile prior to placing the definitive restoration [11]. A provisional restoration that is worn for a period of time can help the peri-implant tissues to mature into a stable and well-formed configuration to be captured and reproduced in the final restoration, a valuable step in a predictable aesthetic outcome [14]. Digital Workflows and Impression Techniques are integrated into the curriculum. The clinician has to record the geometry of the implant and its relation to the surrounding tissues and opposing dentition as well as its geometry in three dimension to fabricate a restoration that fits the implant perfectly. This can be done in a traditional way with a physical impression or a digital impression using a digital intra-oral scan. The accuracy is of paramount importance, as a misfit that would be inconsequential in a tooth-supported situation can, at an implant, cause persisting stress, screw loosening or biological complications [15]. Learn how to take impressions using a conventional impression tray. Know how to take impressions with a conventional impression tray. The standard implant impression uses a precision impression part known

as an impression coping that is placed onto the implant (or on a definitive abutment) and then captured in the impression material, after which a corresponding impression analogue is placed accurately in the working cast. Two techniques are used, illustrated in Figure 5.2.

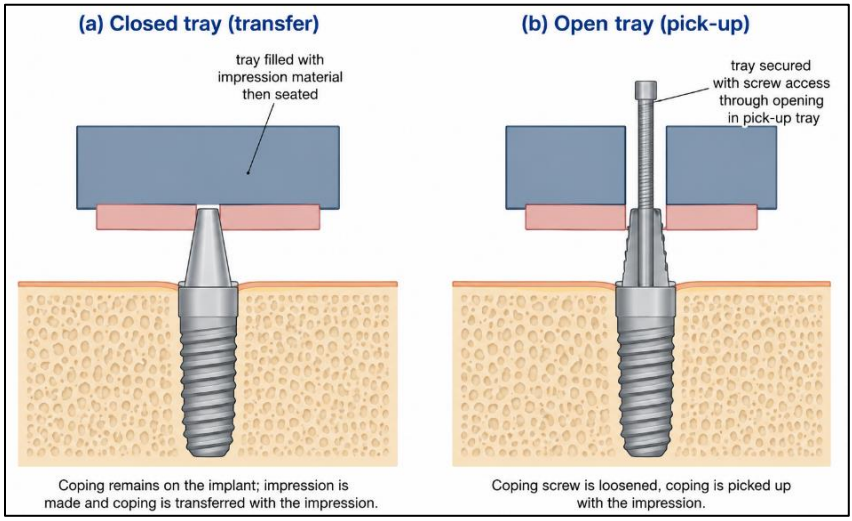

Figure 5.2: Conventional implant impression techniques. In the closed-tray (transfer) technique (a) the tapered coping remains on the implant when the tray is removed and is then re-seated into the impression. In the open-tray (pick-up) technique (b) the coping's guide screw passes through a hole in the tray, is unscrewed, and the coping is picked up within the impression

In the closed-tray (transfer) technique, a tapered impression coping is also employed and coupled with a solid tray, and when the impression is removed, the tapered impression coping is left in the mouth and is later unscrewed and reinserted into the impression. The long guide screw in the open-tray (pick-up) technique is inserted through an opening in a specially prepared tray; the screw is loosened before the impression is taken so that the coping is picked up inside the impression material and removed when the impression is removed. Both closed and open-tray techniques can be used to the advantage of the patient, with the closed-tray technique having less complexity and convenience for single implants or limited access, and the open-tray technique avoiding the potential error of re-seating the coping and is generally preferred for multiple or non-parallel implants [16]. The accuracy of both approaches has been reported with systematic studies showing the same accuracy and laboratory studies showing that both approaches can be accurate, with the open-tray (and splinted) approach becoming more accurate with more implants. A comparison of the techniques is shown below in Table 5.2.

Table 5.2: Comparison of open-tray and closed-tray impression techniques

Feature	Open tray (pick-up)	Closed tray (transfer)
Coping removal	Picked up within the impression.	Remains on the implant; re-seated afterwards.
Tray	Requires access holes over the copings.	Standard solid tray.
Re-seating error	Avoided.	Possible if coping mis-seated.
Best suited to	Multiple / non-parallel implants.	Single implants; limited inter-arch space.
Relative accuracy	Tends to be higher for multiple implants.	Adequate for single units.

Both techniques are validated; selection depends on implant number, angulation, and access.

Digital Impressions

More and more the position of the implant is documented digitally using an intra-oral scanner. The design software then uses the geometry of a component called a scan body to locate the implant and its connection in 3D based on the precisely known geometry that was captured in the scanner. The scan creates a virtual model of the tooth, which is then used to create a computer-generated restoration via computer-aided design and manufacturing (CAD/CAM) technology [17].

There are definite benefits to digital workflows, such as eliminates impression materials and associated patient discomfort, immediate verification on screen, easier to store and communicate, and can reduce

chair time and overall cost in certain situations. They have been well validated for single implants and short-span restorations and systematic comparisons have shown that digital impressions are comparable to conventional impressions for many indications [18]. However, accuracy over long spans is more difficult and errors in the local scan can add up over the span of the arch [19]. Conventional or digital impressions are therefore chosen based on the clinical situation, span of the restoration, and the available technology, and can provide excellent results if executed properly.

Aim to achieve a goal state at the end of a set of exercises. Reach a goal state at the end of a series of exercises. In either case, the objective of the impression is to have the fully seated restoration that seats passively, meaning that it does not strain implants or components. A passive fit is necessary as implants are not mobile and cannot correct a poorly fitted framework; a non-passive fit means that there is a continual preload that can lead to screw loosening, fracture of the components or biological stress. There are a number of ways that the accuracy of the implant position is enhanced and reproduced. If more than

one implant is to be impressed conventionally, the individual impression copings can be splinted together with a rigid material so that they do not move during impression-making as has been demonstrated to enhance accuracy of multiple units. A second error is the choice of a rigid, dimensionally stable impression material and correct handling which further reduces error. For extended reconstructions, the fit of the final framework is checked before finalization (by clinical assessment, one screw test, or by a verification jig) and any misfit is corrected. The cautions are of particular importance if the number of splinted implants is high and the length of the prosthesis is long, exactly where the errors are most critical [21].

ABUTMENT SELECTION

The abutment is the part that extends through soft tissue and is used to hold up the crown or the prosthesis and that is connected with the implant. The choice will affect the fit of the dental restoration, the emergence profile, the aesthetics, and the mechanical characteristics of the dental restoration. There are a number of dimensions along which abutments can differ such as, whether they are prefabricated or custom-made, the material they are fabricated from, and the geometry, which may include any angulation correction between the implant and the restoration [22].

Stock vs Custom Abutments

Stock (prefabricated) abutments are pre-made in a variety of standard heights, diameters, angulations and are chosen and sometimes slightly modified for the individual case. They are cheap, simple, and easy to find and are suitable when the implant is favorably positioned and the emergence requirements are simple. Custom (patient-specific) abutments are created for the specific site, usually by CAD/CAM milling, which enables the emergence profile, margin position, and angulation to be designed patient-specifically [23] to match the contour of the soft tissues and the planned restoration. The value of custom abutments is greatest in the aesthetic area and when axis of the implant needs to be deviated, as it will require more lab work and cost.

Abutment Materials

The main materials used for making abutments are Titanium, Zirconia, and Gold alloy. The standard option, with excellent strength, biocompatibility and track record, is titanium, but its grey color can be seen through thin peri-implant mucosa, affecting the esthetic results. Since zirconia is tooth-colored, it provides excellent esthetic outcome in the anterior area and it is preferred in areas with thin mucosa or high smile line; according to systematic reviews, ceramic and metal abutments have similar survival rates, but zirconia abuttments can be more susceptible to some technical fractures. Randomized comparisons have

yielded positive and comparable clinical outcomes for zirconia and titanium abutments over a number of years, and zirconia should be used when aesthetics is required. Hybrid designs aim to combine the beauty of zirconia with the reliability of the metal connection, in which a zirconia element is bonded to a titanium base that connects to the implant [24].

Table 5.3: Abutment options and their characteristics

Category	Description	Notes / indication
Stock (prefabricated)	Standard sizes /angulations; minimally adjusted.	Economical; favorable implant position.
Custom (CAD/CAM)	Patient-specific geometry.	Optimizes emergence and angulation; aesthetic zone.
Titanium	Metal abutment.	Strong, proven; may show through thin mucosa.
Zirconia	Tooth-colored ceramic.	Superior aesthetics; thin biotype / high smile line.
Titanium-base hybrid	Ceramic bonded to a titanium base.	Combines ceramic aesthetics with a metal connection.
Angulated	Corrects implant-to-restoration axis.	Redirects screw access or crown emergence.

Material and design are chosen to balance strength, aesthetics, and the restorative requirement.

Restorative Materials

The restoration can be made from a number of material systems, all of which have a compromise between strength and aesthetics, depending on the framework or crown of the fixed prosthesis that it is secured in. A traditional metal-ceramic restoration with porcelain fused to a cast or milled metal substructure is an established and proven choice. All-ceramic systems are used more and more; monolithic zirconia has high strength and can be used in posterior and high-load areas, while layered or glass-ceramic materials have high translucency and can be used in the aesthetic zone. The selection of the restorative material is also derived from the same principles as the selection of the abutment — more strength in more function, more translucency in more esthetic; the two materials are selected together, such that a metal-ceramic crown is supported by a titanium abutment in the posterior load-bearing zone, and an all-ceramic crown is supported by a zirconia abutment in the anterior high-stress area. Like any implant component, the material should also allow for the desired implant retention and must have a smooth, clean emergence contour that is easy to clean [25].

PROSTHETIC OPTIONS: SCREW RETAINED VS CEMENT RETAINED

One of the most basic restorative choices involves retention of the prosthesis to the implant,

using a screw or using cement. There are a number of advantages and disadvantages to each mode and these modes have an impact on retrievability, aesthetics, fit of the restoration, and risk of biological complications [26]. The two configurations are compared in Figure 5.3.

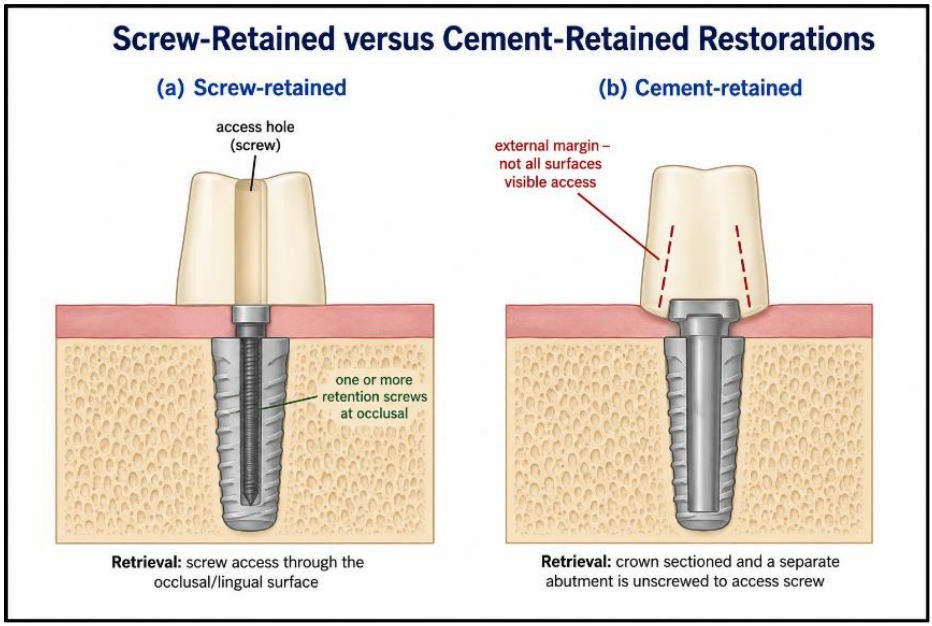

Figure 5.3: Screw-retained (a) versus cement-retained (b) restorations. The screw-retained restoration is secured by a screw through an access channel and is readily retrievable; the cement-retained restoration is luted to a separate abutment, with a cement margin that must be managed to avoid retained excess cement

Screw-Retained Restorations

A screw-retained restoration is a restoration that is directly fastened to the implant or abutment by a screw that fits into an access channel formed in the restoration that is then closed. Its great benefit is that it can be easily removed without any damage for any repair, hygiene, or revision, by simply unscrewing it.

Also, it eliminates the biological risk and cement. The disadvantages are that it may affect the aesthetics of the implant due to the access channel being installed in the screw access channel, and also because it may require an appropriate amount of restorative space and a favorable implant axis for the access channel to be brought to an appropriate position, especially in the occlusal surface (if the angle is at a visible or functional surface) [27].

Cement-Retained Restorations

A cement-retained restoration is luted to a separate abutment, similar to a conventional prepared-tooth crown. It provides freedom of a visible access channel, occlusal surface that may be slightly better, passive seating and some compensation for implant angulation. Biological disadvantage is its main disadvantage as cement extruded beyond the restoration margin during cementation is very hard to remove, particularly when the margin is subgingival, and excess cement has been shown to be very closely associated with peri-implant inflammation and peri-implantitis. In a clinical endoscopic study, Wilson identified excess cement as being associated with the presence of signs of peri-implant disease in most of the cases examined [28] and other studies later confirmed the relationship between excess cement and peri-implant disease, especially deep margin zones.

Comparative Evidence and Selection

Both the two types of retention have been associated with high overall survival in systematic reviews, with screw-retained restorations having more technical complications (including screw loosening, access channel problems) and cement-retained having more biological complications (including those related to residual cement), though more easily retrieved in the latter if they occur. A multi-center prospective investigation revealed similar peri-implant soft-tissue health for both the cementation modes if appropriate technique and margin placement were carefully performed [29], confirming that peri-implant soft-tissue health is strongly related to the cementation technique and margin position. The comparison is summarized in Table 5.4.

Table 5.4: Screw-retained versus cement-retained restorations

Feature	Screw-retained	Cement-retained
Retrievability	Excellent — simply unscrewed.	Difficult — may require sectioning.
Aesthetics	Access channel may be visible.	No access channel; freer aesthetics.
Cement-related risk	None.	Retained excess cement risks peri-implantitis.
Angulation tolerance	Requires favorable axis.	Some compensation for angulation.
Restorative space	Needs space for the channel.	More forgiving.
Typical complications	Screw loosening; technical.	Biological (cement); harder to retrieve.

Both perform well; selection weighs retrievability, aesthetics, angulation, and cement risk.

Managing Cementation

Re There is a biological hazard for a cement retained restoration, which is almost entirely related to excess cement, and thus can be greatly reduced by technique. The best single approach is to maintain the restoration margin at or just at the mucogingival level and not deep subgingivally, and thus can see and remove excess cement; the deeper the restoration margins the more cement that will be undetected. A thin layer of cement placed in the intaglio area just covering the coronal surface and a cement filled technique, seating the crown onto a replica of the denture base prior to cementation to express and remove excess cement and then definitive cementation can minimize the amount of cement applied. The margins are carefully cleaned after seating, and the site inspected, radiographically when indicated, to ensure that there is no cement. If it is not possible to ensure these precautions are taken (such as a deep margin in an aesthetically sensitive area), then a screw-retained design may be a more secure option [30]. The use of sound cementation technique, therefore, transforms a true biological risk into a manageable risk and its omission is a preventable cause of peri-implant disease.

OCCLUSAL CONSIDERATIONS

One of the factors involved in long-term mechanical success of an implant restoration is the way it meets the opposing dentition – its occlusion. A natural tooth is anchored in the jaw by the periodontal ligament and is able to move slightly and feel the strain, while an Osseo integrated implant is fixed in the bone and does not have this proprioceptive and shock-absorbing ability. Occlusal forces are thus more directly applied to the bone and to the different components, and overload can lead to technical complications including screw loosening, fracture of the different components and, in some analyses, to marginal bone loss [31].

The principles of implant-protected occlusion aim to help control these forces: distribute force along the long axis of the implant, eliminate lateral and cantilever forces if possible, create lighter contacts on the implant than on neighboring natural teeth, which help to distribute initial force, and avoid interferences during excursive movements. Attention to occlusion during the restoration and maintenance throughout the life of the prosthesis can maintain the integrity of the prosthesis and its integration [32]. The principles are applied from the single crown to the full-arch reconstruction, depending on the complexity of the cases.

SUMMARY AND CLINICAL PERSPECTIVE

The prosthetic phase involves making an integrated implant ready for function, in a clearly defined sequence: confirmation and, if necessary, acceleration of the healing process leading to the implant; uncovering of submerged implants and conditioning of the

surrounding soft tissue; documentation of the position of the implant by the conventional or digital method; selection of a suitable abutment for each implant location and the required aesthetic demand; selection of a retention method that is retrievable, aesthetically pleasing and biologically safe. Every step builds upon the next and each is backed by a solid evidence base [1].

Several themes recur. Previously loading protocols were based on one conservative protocol, but now have evolved to a range dependent on the implant surface and the type of loading case, with the goal of improving primary stability [5]. Traditional impressions are complemented by digital workflows, which can be employed in a complementary way in suitable indications and can be as accurate as traditional impressions [17]. The selection of abutment and retention system is not a dogma, and it is known that there are compromises to consider, such as zirconia and titanium aesthetics and reliability, as well as retrievability and freedom of cement. The cement has been well documented as a biological hazard [25].

It should be noted that complications of implant restorations are mostly technical in nature and can be well controlled and that the long-term survival of well-performed implant-supported crowns and fixed prostheses is excellent [31,33]. However, there are some biological and technical problems, such as screw loosening, veneer fracture and cement-associated inflammation, which can occur, and these are addressed in the right way in this phase, through sound restorative decisions [30,32]. Chapter 6 focuses on the maintenance and long-term care that can help to sustain these benefits, and the recognition and management of complications that still occur.

❑❑❑

CHAPTER 6

PERI-IMPLANT HEALTH, COMPLICATIONS, AND LONG-TERM MAINTENANCE

An implant restoration is not the end of treatment but the beginning of a lifetime of care. The bone and soft tissue around an implant remain vulnerable to inflammation and breakdown, the prosthetic components are subject to mechanical wear and failure, and the long-term success of the whole enterprise depends on sustained maintenance by both patient and clinician. This closing chapter addresses that long horizon. It describes what healthy peri-implant tissue looks like, how the peri-implant diseases — mucositis and peri-implantitis — arise, are recognized, and are managed, how mechanical and technical complications are handled, and how a program of supportive care and follow-up protects the investment of the preceding chapters over the years and decades that follow.

INTRODUCTION

The reported high implant survival rates may lead one to think that, provided an implant is integrated and restored, no further intervention is necessary. This impression is wrong. Biological and mechanical complications may develop with implants and their restorations, which can result in loss of the implant or failure of the restoration, if not recognized or managed. The most relevant of these are the peri-implant diseases, inflammatory diseases of the tissues around the implant, which were formally defined and classified at the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions [1].

The main idea of this chapter is prevention and vigilance in the pursuit of long-term success. Most biological complications can be prevented with good plaque control and periodic maintenance from a dental professional and most mechanical complications are treatable if caught early. The clinician's role following restoration is then to implement a monitoring and supportive care system, educate and motivate the patient and intervene promptly and appropriately when issues arise. The chapters which precede this describe the proper placement and reinsertion of an implant; this one describes the proper maintenance of an implant.

PERI-IMPLANT HEALTH

Health needs to be defined before disease can be recognized. The following are clinical criteria to consider regarding the absence of clinical signs of peri-implant inflammation:

No redness or swelling on gentle probing, no bleeding or suppuration on gentle probing, and no progressive loss of supporting bone beyond the natural peri-implant remodeling after implant placement. Importantly, peri-implant health can be found around the implants with normal and reduced bone support, but not necessarily a specific bone level: the absence of inflammation and presence of no ongoing bone loss defines the health, and not the bone level [2].

The soft tissue surrounding an implant is different in several key respects from the periodontium of a natural tooth, with implications for susceptibility to disease. The peri-implant mucosa is anchored to the implant or abutment by a junctional epithelium and a layer of connective tissue, but the area lacks cementum, there is no inserting periodontal ligament, and there are no perpendicular collagen fibers, the fibers lying more or less parallel to the implant surface [3]. The vascularity of the connective tissue is relatively less and its collage Nity is relatively more. As a consequence of these features, inflammation following an implantation could develop more easily and rapidly than around a tooth, and once it has occurred, the peri-implant seal may be less efficient in preventing the spread of the insult to the apices [4] of the implant.

Probing and Peri-implant Sulcus

One interesting implication of this anatomy: probing around implants should be interpreted differently than probing around teeth. As the connective-tissue fibers are not attached to the implant, a probe pushed forward with the same force will advance further into the surrounding mucosa than it does into a normal tooth; the depth of probing that is normal for a particular implant will depend on the thickness of the surrounding mucosa and the depth where the implant was placed. Hence, the peri-implant probing depth of any given implant is not the "normal" value but rather the increase or decrease of the probing depth as time passes, in addition to the presence or absence of bleeding [5]. To prevent disruption of the delicate seal, a gentle probing force is applied, and the same site is monitored regularly allowing increases to be reliably detected. The principles outlined above help to avoid over-diagnosis of a sulcus that is not shallow, and under-recognition of a true progressive deepening of the sulcus. There are 2 types of peri-implant diseases recognized: Peri-implant mucositis is a peri-implant inflammatory lesion that is associated with bleeding on probing of the peri-implant tissue with visual signs of inflammation without progressive bone loss. It is the peri-implant equivalent of gingivitis and reversible; that is, if the biofilm that leads to its development can be removed, the tissue can heal [6]. Inflammatory gingivitis that leads to progressive loss of supporting bone that occurs beyond the initial bone remodeling; bleeding and/or suppuration on probing and often increased probing depths are characteristics of peri-implantitis. It is the more serious condition and if left untreated, can lead to implant loss [7]. Figure 6.1 shows the difference between health, mucositis and peri-implantitis.

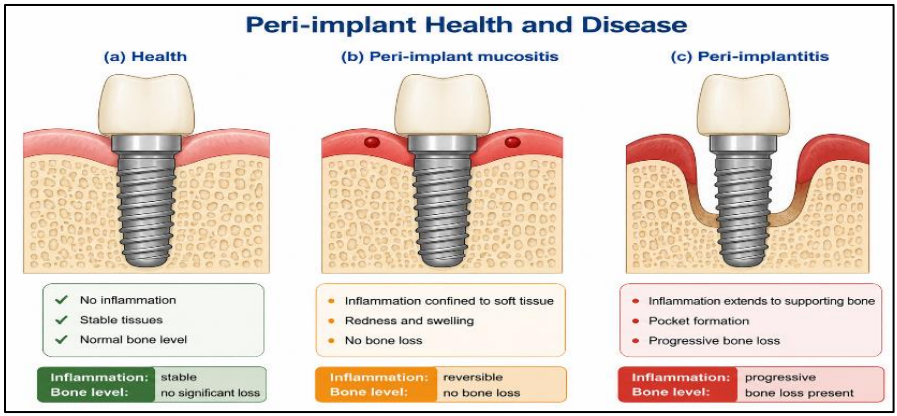

Figure 6.1: Peri-implant conditions. (a) Health: no inflammation, stable bone. (b) Peri-implant mucositis: inflammation and bleeding on probing but no bone loss — reversible. (c) Peri-implantitis: inflammation with progressive crestal bone loss

The major difference between the two is the presence or lack of progressive bone loss (Section 6.5), and this is why baseline records and comparisons between them and over time are so important. The case definitions proposed in the 2017 World Workshop [5] are summarized in Table 6.1.

Table 6.1: Case definitions of peri-implant conditions (2017 World Workshop)

Condition	Inflammation (BoP / suppuration)	Bone / probing changes
Peri-implant health	Absent — no bleeding on gentle probing.	No bone loss beyond initial remodeling.
Peri-implant mucositis	Present — bleeding on probing, visual inflammation.	No progressive bone loss.
Peri-implantitis	Present — bleeding and/or suppuration.	Progressive bone loss; usually increased probing depth.

BoP: bleeding on probing. Diagnosis of peri-implantitis relies on evidence of progressive bone loss.

The peri-implant diseases are common. Systematic reviews of the epidemiology of peri-implant mucositis and peri-implantitis report high prevalence (a significant minority to a majority) of peri-implant mucositis and peri-implantitis in implant patients, with estimates that vary considerably depending on case definition [8]. This high prevalence highlights the fact that peri-implant disease is not a bad break but a routine problem that every implant clinician will encounter in his or her clinical practice and should strive to prevent, identify, and treat.

AETIOLOGY AND RISK FACTORS

Bacterial biofilm (dental plaque) build up on the tooth implant and restoration surfaces is the main cause of peri-implant inflammation. Experimental accumulation of plaque around implants showed the same pattern of a reversible inflammatory response in the peri-implant mucosa as in experimental gingivitis around teeth, which resolved after improvement of the hygiene [9]. Peri-implant mucositis is therefore recognized as a plaque-induced host-mediated inflammatory reaction, and is the initial stage from which peri-implantitis could develop if the inflammation continues and worsens.

Biofilm is the necessary cause, but a number of factors modify a patient's susceptibility to disease and likelihood for progression. An established risk factor is a history of periodontitis, as patients with teeth that were lost due to periodontal disease have an increased risk for peri-implantitis; there is a common susceptibility and common microbiology. Cigarette smoking increases the time to healing and affects the host response and has been linked to worse implant outcomes. Gingivitis and the lack of regular supportive maintenance is a huge risk. Local factors also play a role: for example, cement residues from cement-retained restorations, as discussed in Chapter 5, can cause a chronic inflammatory response. Other proposed risk factors are poorly controlled diabetes, certain designs of implants or restorations which make them difficult to clean, and absence of keratinized mucosa [10]. These are summarized in Table 6.2.

The Peri-implant Microbiology

In general, bacterial flora surrounding peri-implant health and disease are similar to those surrounding teeth: peri-implant disease is correlated with an increase in the complexity of the bacterial flora, which is predominantly anaerobic and Gram-negative. Since the microbiology of implants is similar to that of teeth, the natural teeth can serve as a source of implant colonization, which is one of the many reasons why periodontal health is important to peri-implant health; and periodontal disease should be treated and controlled before and during implant therapy [11]. This common microbiology is also why the same principles of biofilm control that are used for periodontal care are used specifically with peri-implant tissues and why patients who are susceptible to periodontal disease are likely susceptible to peri-implant disease. The clinical implication is that the unit of preventive care is the whole mouth, and not the implant alone.

Table 6.2: Risk factors and indicators for peri-implant disease

Factor	Relationship to peri-implant disease
Biofilm/poor plaque control	The primary cause of peri-implant inflammation.
History of periodontitis	Well-established risk indicator for peri-implantitis.

Table 6.2 Continued….	
Cigarette smoking	Impairs healing and host response; poorer outcomes.
Lack of supportive maintenance	Strongly increases risk of disease onset and progression.
Residual excess cement	Local irritant; provokes persistent inflammation.
Poorly controlled diabetes	Proposed systemic modifier of the host response.
Non-cleansable design / restoration	Impedes plaque control; favors biofilm accumulation.
Deficient keratinized mucosa	Associated with more inflammation and discomfort in cleaning.

Biofilm is the necessary cause; the remaining factors modify susceptibility and progression.

DIAGNOSIS AND MONITORING

All clinical tools used around a tooth are applicable to peri-implant conditions, but must be used with sensitivity to the unique characteristics of implants. Probing depth, bleeding on probing, suppuration, and over time the radiographic bone level are essential parameters, while implant mobility is a late and worrisome sign denoting total loss of implant integration instead of early disease [12,13].

Probing around implants is done gently, any bleeding around the implant means that it is inflamed, any probing depth increase over time means loss of attachment and bone. Swelling with pus is an indication of live infection, usually quite advanced. It is important to evaluate the level of peri-implant bone loss with radiographs and, importantly, its progression over time; since peri-implantitis is diagnosed by the progressive loss of peri-implant bone, it is not possible to appreciate it on a single radiograph alone. Therefore, it is of great value to have a set of baseline records (probing depths, and a radiograph at the time that a restoration is placed) against which future measurements are made [14]. Table 6.3 relates the clinical findings to the three peri-implant conditions.

Table 6.3: Clinical findings in health, mucositis, and peri-implantitis

Parameter	Health	Mucositis	Peri-implantitis
Bleeding on probing	Absent	Present	Present
Suppuration	Absent	Usually, absent	Often present
Probing depth	Stable	May increase (inflammation)	Increased
Radiographic bone loss	None (post-remodeling)	None	Progressive
Mobility	Absent	Absent	Absent until late / total failure

Interpretation depends on comparison with baseline records established at restoration.

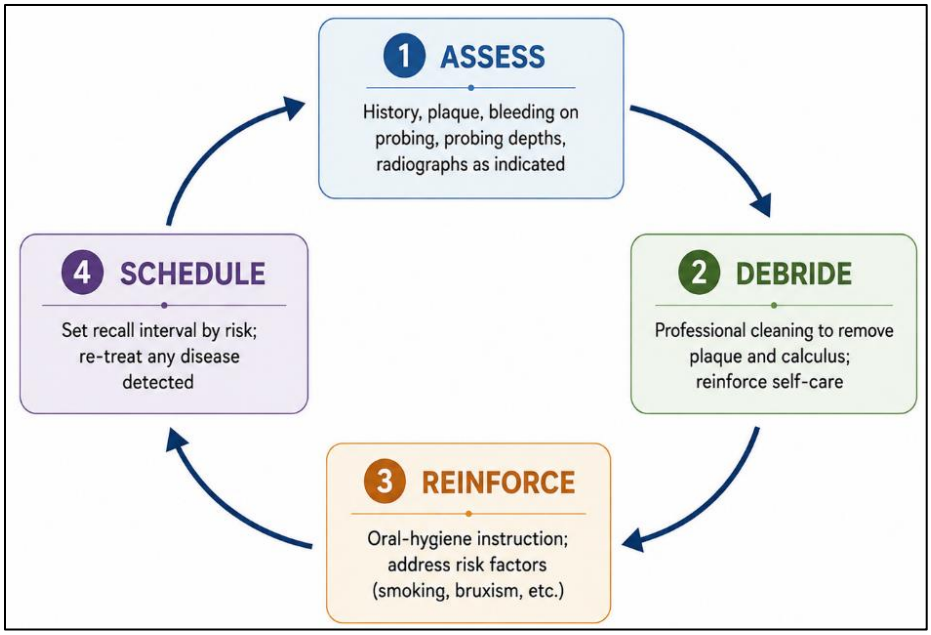

Figure 6.2: The supportive peri-implant care recall cycle: assess the tissues, professionally debride, reinforce home care and address risk factors, and schedule the next recall according to risk

It should be noted that probing and interpretation of radiographs around implants have specific limitations: probing is more likely to disrupt the peri-implant seal than the periodontal attachment, the contour of the restoration can make it more difficult to access the radiograph, and the radiopaque nature of the implant can obscure the bone interface region. While all of these tools are essential, they must be used wisely and consistently; evaluations of their reliability stress the importance of the standardized method and serial comparison rather than any single measure [15]. Any supportive care of the implant and its surrounding tissue will be covered. Supportive preimplant care and hygiene protocols will be addressed. As peri-implant disease is biofilm-related, the key to its prevention is the treatment of both the oral biofilm (home and the clinic at regular maintenance appointments). The provision of a structured program of supportive peri-implant care is the number one important step in preventing peri-implant disease and early detection, and should be considered an additional mandatory element of implant therapy, not an extra added-on cost. The recall cycle is shown in Figure 6.3.

Home Care

The patient's daily care of their plaque is the cornerstone of peri-implant health. Patients are taught in detail but gently how to clean the implant restoration and its sometimes-intricate shape, using a toothbrush (either hand or powered) and interdental aids (interdental brushes, floss or specialized devices for cleaning the implant as appropriate depending on the design of the restoration). The restoration should be planned and shaped from the beginning to allow for use of these aids, otherwise it is an invitation to disease. At every maintenance appointment, patient motivation and technique are revisited, as well-trained habits can fall by the wayside over time [16].

Professional Maintenance

At recall, a structured supportive-care visit is conducted, which includes assessment of the peri-implant tissues for signs of disease outlined above, removal of professional biofilm and calculus, review of home care and reinforcement, address modifiable risk factors and determine the interval to the next visit based on patient risk. There is systematic evidence that maintenance reduces substantially peri-implant disease; and that interruptions of maintenance are associated with an increase in peri-implantitis [17]. Table 6.4 shows the elements of a supportive-care visit.

Table 6.4: Components of a supportive peri-implant care visit

Component	Actions
Assessment	Update history; assess plaque, bleeding on probing, suppuration, probing depth; radiographs as indicated.
Professional	Remove biofilm and calculus using implant-safe instruments; polish.
Component debridement	**Actions**
Reinforcement	Review and re-instruct home care; disclose plaque if helpful.
Risk-factor management	Address smoking, glycemic control, and other modifiable risks.
Recall scheduling	Set the interval by individual risk; arrange treatment of any disease found.

The visit both prevents disease and provides the serial data on which early diagnosis depends.

The selection of instruments to use for professional cleaning around implants is especially important. The relatively soft surface of titanium may be scratched by hard metal instruments and conventional ultrasonic tips, which can make it more likely to collect more

plaque. Therefore, instruments and tips that are not known to harm the implant surface should be preferred to debride the surface itself and reviews of instrumentation focus on removing the biofilm without causing damage to the surface [18].

Determining the Recall Interval

There is no fixed time between maintenance visits; it is determined based on an individual patient's risk. If you have had periodontal disease, poor plaque control or a smoking habit, or have a known problem with peri-implant disease, you will need more frequent recall visits, which may be every few months, to detect and treat any inflammation that is present before it gets worse. If the patient has no significant risk factors, healthy tissues and good hygiene, then they can be seen less often. The interval is reassessed at every visit based on the results of the tissues, and reduced if they show signs of inflammation. In this way the recall schedule is not a fixed routine, but a very useful tool of risk management, which focuses the professional attention where it is most needed. One of the most important things a clinician can do to help ensure the long-term success of their patients is to help them understand the importance of, and follow their, recall program, as lack of maintenance is one of the biggest factors that can also lead to peri-implant disease [19,20]. The hallmark of peri-implant mucositis prevention is its recognition and treatment as this condition can be reversed and is a precursor to peri-implantitis. It is basically non-surgical, anti-infective treatment: a complete professional removal of the biofilm and any irritant local factors such as any residual cement or overhanging margins of the restoration and effective home care re-establishment. Adjuncts like antiseptics, or locally applied, can aid this mechanical approach. Mucositis can be healed by using the proper technique for biofilm removal and maintaining a proper hygiene [21].

The clinical value of the mucositis treatment is that it is a reversible phase, prior to the onset of bone loss. In a way, the primary prevention of peri-implantitis is the effective management of mucositis: when mucositis is managed, the disease doesn't get worse and the supporting bone remains intact. That is why a bleeding on probing at a maintenance visit isn't a trivial finding, but a call to action.

MANAGEMENT OF PERI-IMPLANTITIS

When bone loss is present, it is called peri-implantitis and treatment is more challenging and less predictable. The aims of treatment will be to stop the disease from progressing, to remove the infection and where possible to regenerate lost bone or create a maintainable situation by cleaning the surface of the implant that was exposed. The treatment is gradual, step-wise and can increase from non-surgical to surgical treatment based on severity and response [22].

A Cumulative, Stepwise Approach

One commonly employed guideline for the organization of this escalation is called cumulative interceptive supportive therapy (CIST) where interventions are introduced progressively as the clinical signs increase in severity. Mechanical debridement is used for early lesion, antiseptic therapy for bleeding and probing depth increase, systemic or local antibiotics for deeper, actively infected lesion, surgical therapy for established peri-implantitis. Explanation is performed only if these implants have advanced and non-maintainable bone loss or implant mobility [23]. This framework is shown in a pictorial form in Figure 6.3.

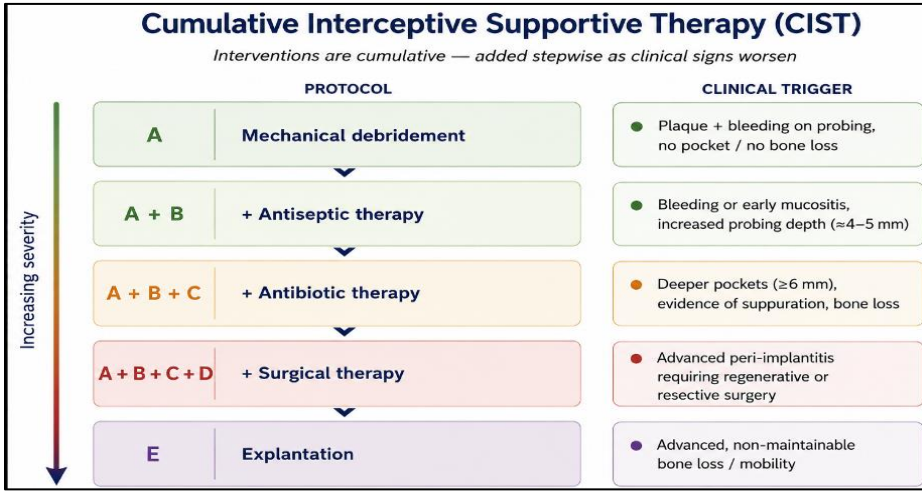

Figure 6.3: The cumulative interceptive supportive therapy (CIST) concept. Interventions are cumulative, added stepwise (A → B → C → D, with explanation, E, as a last resort) as the severity of the clinical signs increases

Non-surgical and Surgical Therapy

Mechanical debridement of the implant surface, possibly combined with an antiseptic and/or antibiotic, is usually the initial treatment and may be effective for treating some lesions, but it may not be effective in decontaminating a rough, threaded implant surface within a bony defect and is often not sufficient on its own to treat established peri-implantitis. Surgical intervention: Exposure of contaminated surface for thorough decontamination and access to the bony defect for correction. There are two approaches to the surgical correction of a bone defect: respective, in which pockets are drained and the bone and soft tissue are recontoured to allow for a cleanable situation, and regenerative, in which an attempt is made to fill the bony defect with a graft (usually under a barrier membrane, as described in Chapter

4), to restore the height and support. The decision depends on the morphology of the defect: contained (circumferential) defects are more suitable for regeneration, while horizontal or unfavorable defects are better resected [24].

An important and challenging part of all surgical treatments is the cleansing of the implant surface itself. There are a variety of mechanical, chemical, and other techniques that have been tested, but none has been conclusively proven to be superior. Evidence for treatment of peri-implantitis itself is expanding but is less solid than evidence for periodontal treatment, and no single method has been demonstrated as being clearly superior [25]. The results are not always consistent and reoccurrence is possible, hence the importance of prevention by the management of mucositis and the maintenance program described above. The approaches to treatment are summarized in Table 6.5.

Table 6.5: Approaches to the management of peri-implant disease

Approach	Methods	Typical indication
Non-surgical / anti-infective	Mechanical debridement; ± antiseptics; ± antibiotics.	Mucositis; early peri-implantitis; initial phase.
Resective surgery	Flap access, decontamination, pocket reduction, osseous recontouring.	Peri-implantitis with unfavorable / horizontal defects.
Regenerative surgery	Flap access, decontamination, bone graft ± membrane.	Contained, favorable intrabody defects.
Explanation	Removal of the implant.	Advanced, non-maintainable bone loss or mobility.

Treatment is escalated cumulatively; decontamination of the implant surface is a shared challenge.

Adjunctive and Emerging Methods

There are many other methods that have been developed to help decontaminate the complex, roughened, and threaded implant surface better than mechanical instrumentation alone. Air-abrasive (air-polishing) devices can access threads and irregularities not possible by hand instruments; antiseptics and chemical agents are used to disinfect the exposed surface; and lasers are being studied for their ability to disinfect and to reduce inflammation. Sometimes in more advanced cases, the surface of the exposed, contaminated implant threads will be smoothed and polished mechanically, called implantoplasty, that makes it easier and less retentive of biofilm. These are still in the process of being developed, and systematic reviews generally find that whilst there are some promising adjuncts, none has yet been proven as clearly superior to conventional treatment with care [26]. They should therefore be considered as options for mechanical or surgical management and are individualized for the case and the clinician's experience.

MECHANICAL/TECHNICAL COMPLICATIONS

In addition to the biological complications, mechanical and technical complications occur in the screw, the components and the prosthetic material of the implant restoration. These summed up, are common during the life of a restoration, but most are easily controlled if the restoration is designed to be retrievable, and the complication is caught early [27].

The most common technical problem is loosening of the abutment or of the prosthesis's screws, which is manifested by slight mobility or rotation of the prostheses and is fixed by retightening the screw or by replacement if a non-passive fit or an occlusal overload is determined to be the cause of the problem. Screw fracture is rare but more serious and will need the removal of the fractured piece. The most frequent fracture or chipping of the restoration surface (porcelain or resin) occurs with various degrees of severity, from simple chips that can be polished or repaired to fractures which must be remake. Rarely, the framework itself can break, and — even less frequently — the implant fixture can break, which typically requires removal of the implant. Many of these complications are tied to occlusal overload, parafunction or a non-passive fit and are related to the restorative principles of Chapter 5. Fixed implant reconstruction is documented to have a number of technical complications including screw loosening and veneer fracture with systematic review of these operations over 5 years and beyond showing this. Table 6.6 presents some of the most frequently encountered mechanical complications and how to manage them [28].

Table 6.6: Common mechanical and technical complications

Complication	**Presentation**		**Management**		
Screw loosening	Mobility/rotation restoration.	Of the	Retighten to torque or replace; check fit and occlusion.		
Screw fracture	Loose restoration; fragment.	Retained	Retrieve screw.	Fragment;	Replace
Veneer Chipping / fracture	Chipped or porcelain/resin.	Fractured	Polish, repair, or remake as needed.		
Framework fracture	Fracture of the substructure.		Remake; design.	Reassess	Load
Implant fracture	Fracture of the fixture (rare).		Usually removal of the implant.		
Wear / loss of retention	Cemented crown loosens; wear		Recement; replace worn		
Complication	Presentation		Management		
	of components.		components.		

Retrievable (e.g. screw-retained) designs greatly simplify the management of these complications.

Preventing Mechanical Complications

Again, like with the biological complications, prevention is better than repair. Many mechanical issues can be avoided at restorative time, and confirmed at maintenance: ensuring the passive framework fit so that no occlusal strain is applied to the components; screw tightening to the manufacturer's specification and re-checking where indicated; providing a favorable distribution of occlusal load and implant protected occlusion (light, axially directed contacts described in Chapter 5); managing parafunctional habits, for example with an occlusal splint if the patient complains of a clenching/grinding habit. The restoration is checked every time it is called for to see if there are any early symptoms of mechanical issues, such as loose screws, chips that are coming out, or wear of the occlusal surface, and this can be corrected before it becomes a more serious problem. This way, the mechanical and biological aspects of maintenance go hand in hand, resulting in the protection of the restoration and the underpinning implant [29]. This course examines the patient follow-up and long-term outcomes of patients with hearing loss. These complications are recognized, prevented and treated by a program of long-term follow-up. Once the restoration is delivered, the patient is placed on a recall schedule that is based on the individual's risk frequent for patients with periodontal disease history, those who don't maintain good plaque control, smokers, and established periodontal disease, and less frequent for patients at low risk and maintaining their disease well. Each recall is a combination of supportive care measures from Section 6.6 and an evaluation of the biological and mechanical complications of this chapter and allows identification of problems at an easily treatable stage. For the sake of the success criteria introduced in Chapter 1, it is helpful to differentiate between implant survival (tightly in place) and implant success (plus no pain, infection, progressive bone loss, and mechanical failure). An implant can be present, but not be successful, such as when an implant is impacted by peri-implantitis or has an intermittently compromised restoration. The long-term results, however, are very favorable and are reported to be high (10-year and more implant survival) while biological and technical complications are low but not negligible and maintenance is meant to take care of them [30]. These are reminders that implant therapy has been a great success, but also remind us of the need for the watchfulness espoused in this chapter. Follow-up also entails honest communication about prognosis. If peri-implantitis is found, the clinician evaluates the amount of bone loss, the maintainability of the site, and the patient's ability to manage the modifiable risk factors and communicates this to the patient, who makes the final decision regarding treatment [31]. When there is significant bone loss, it is not realistic to expect to ever come up with a naturalistic solution, or when repeated failures with a compromised fixture occur, the best plan is to contemplate future removal of the implant and reconsideration of the site. These decisions are made openly and in light of the likely benefits and harms of each choice, which shows respect for

the patient, and provides realistic expectations [32]. The long-term care of the implant is a shared, evidence-informed approach that is a natural extension of the patient-centered planning process that started in Chapter 2.

SUMMARY AND CLINICAL PERSPECTIVE

The fundamental principle of long-term care of dental implants relies on the fact that tissues surrounding the implant and the components that restore it need to be protected from the biological and mechanical insults of a lifetime of function. The process of peri-implant health loss involves the reversible step of mucositis, and the destructive step of peri-implantitis, which is related to the presence of bacterial biofilm and influenced by risk factors like history of periodontitis, smoking, inadequate maintenance and residual cement [2,12,17,33].

The diagnosis is based on serial, consistent probing, bleeding and suppuration, along with baseline radiographs and bone levels [19]. Effective peri-implant maintenance in the home and an organized program of supportive peri-implant maintenance is the one most important measure for prevention [23]. The reversible stage of mucositis can be non-surgically treated and is the first step in the "prevention" of peri-implantitis [27] while the established peri-implantitis can be treated by a progressive escalation from non-surgical to surgical treatment, with less predictable outcomes which make prevention all the more important [30]. Mechanical problems occur frequently and they are well controlled — even more so, if the restoration is retrievable [32].

This chapter brings the book to a close. All the chapters (Chapters 1 through 5) give a complete, working implant; the maintenance and long-term care described here preserve it. A clinician who comprehends the entire process — and who also has the technical skill, lifetime attention and dedication to prevention — can provide patients with results that are long-lasting and predictable with the help of modern implant dentistry.

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