Implant survival and Biologic complication rates of monolithic zirconia implant-supported fixed complete-arch dental prostheses

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ABSTRACT

Objective: To assess the implant survival and biologic complications observed with monolithic zirconia implant-supported fixed complete dental prostheses (IFCDPs) in completely edentulous patients after a clinical follow-up period of at least one year. In addition, the secondary objective was to report on the patient's subjective assessment of the treatment through a questionnaire in order to evaluate the functional, physical, and psychological outcomes of the IFCDPs.

Material and Methods: This study was an observational single-center retrospective clinical cohort study performed in the Division of Postgraduate Prosthodontics at Tufts University School of Dental Medicine (TUSDM). A convenience sample of subjects that underwent treatment with zirconia IFCDPs at TUSDM was used.

Results: The study involved 44 patients, consisting of 20 females (45.5%) and 24 males (54.5%), and 61 arches, consisting of 32 maxillary arches, comprising 52.46%, and 29 mandibular arches, accounting for 47.54% of the total. who were predominantly White (95.1%) and Non-Hispanic (88.5%). The patients demonstrated a low prevalence of smoking (13.1%) and diabetes (6.6%). Medical history reviews indicated no reports of cancer or jaw radiation, and only a minimal use of bisphosphonates (3.3%).

The study observed several types of biological complications, though major complications were infrequent. Implant loss and advanced bone loss (>2mm) were recorded in 0.8% and 3.4% of cases, respectively. Minor complications were more prevalent, with issues such as soft tissue hyperplasia and recession affecting a small percentage of the cohort. The most common issues encountered were related to implant maintenance, including the management of plaque and the stability of the implants over time.

This comprehensive assessment helps delineate the various factors influencing the success and longevity of monolithic zirconia IFCDPs, highlighting both the effectiveness and areas for improvement in clinical practices.

Conclusion: Given the frequent occurrence of biological complications, it is imperative for the clinician to be aware of the incidence rates to implement personalized maintenance and recall protocols for their patients.

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Introduction

Complete edentulism, or the total loss of natural teeth, is a chronic condition that cannot be reversed. In addition to physical impairment, it can also be classified as a disability due to its impact on critical everyday functions such as speech, eating, and smiling. When all-natural teeth are missing, individuals may experience a decreased ability to chew food effectively and articulate words, [1] leading to social embarrassment, low self-esteem, and isolation. The absence of teeth can also affect facial appearance due to the lack of facial support from teeth, making it look older. Modifications in nutrition are required; individuals tend to eat more soft food and less protein and hard vegetables, resulting in a reduced quality of life. [2] [3, 4]The prevalence of edentulism is influenced by socioeconomic factors,[5] such as dental education, access to dental hygiene tools, dental visits, and, in some cases, lack of access to fluoridated water,[4] with a lower occurrence among wealthier populations. [6]

Treatments for edentulism used to be only palliative, aiming to improve function and quality of life for edentulous patients. Conventional removable prostheses are the most affordable option,[7] but they often have drawbacks, such as reduced retention and discomfort while chewing. [8, 9] As a result, implant-retained prostheses, whether removable or fixed, have gained popularity despite being significantly more expensive. Due to these reasons, the demand for implant full-mouth reconstructions for completely edentulous patients is expected to continue increasing.

Due to the escalating popularity of dental implants and the advancements achieved in dental implant systems available on the market, the efficacy of osseointegrated implants has been substantiated for both partially and completely edentulous patients. [10, 11]

Dental implants have significantly improved the quality of life for edentulous patients by addressing both functional and psychological challenges associated with tooth loss. Studies have shown that implant-supported prosthetic rehabilitation enhances oral health-related quality of life (OHRQoL) by improving chewing efficiency, speech clarity, and comfort, compared to traditional dentures. These benefits allow patients to enjoy a broader diet and maintain better nutritional health[12]

Psychological and social well-being also improves with dental implant rehabilitation. Patients report reduced self-consciousness and increased confidence in social interactions due to the natural look and stable function of implants. For instance, assessments using the OHIP-14 and GOHAI questionnaires demonstrate significant reductions in psychological discomfort, physical disability, and social limitations after implant treatments [12]

Furthermore, dental implants contribute to long-term oral health by preserving jawbone structure, which prevents bone resorption, which is commonly associated with tooth loss. This

structural stability helps maintain facial aesthetics over time, providing lasting physical and emotional benefits.[13]
These findings underscore the transformative impact of dental implants, making them a vital solution for improving the functional and emotional well-being of individuals with complete tooth loss.[14, 15]

The evolution of dental implants has been marked by significant advancements, improving the effectiveness and predictability of implant-based restorations. Initially, dental implants were introduced in the 1960s by Per-Ingvar Brånemark, who discovered the process of osseointegration and coined the term, [16] which is defined as the direct structural and functional connection between living bone and the surface of a load-bearing artificial implant where titanium could bond with bone. This laid the foundation for modern dental implantology, which has since seen several key developments.
Over the years, implant materials and designs have significantly advanced. Initially, titanium implants dominated due to their biocompatibility and strength. In the past, smooth surface implants were implemented first; nowadays, moderately rough implants have shown better clinical use.[16] [17]
Today, advanced implant surface treatments, whether additive such as plasma-sprayed titanium and hydroxyapatite coatings, or substactive such as sand blasting, acid etching and anodization, improve osseointegration by enhancing the interaction between the implant surface and living bone cells.[18]

Implant companies, in collaboration with engineers, scientists, and dentists, came up with different implant shapes and surface treatments.
Here is how various companies have adopted or developed the mentioned implant surface treatments:

Machined Titanium (Brånemark System):
The Brånemark implant system by Nobel Biocare initially used machined titanium, which was the standard for implant surfaces in the 1960s. However, as research progressed, surface modifications to enhance osseointegration were introduced, such as SLA and TiUnite.
Hydroxyapatite (HA, Sulzer):
Sulzer (now part of Biomet 3i) was a pioneer in using hydroxyapatite (HA) coatings for implants. With average roughness between 3–7 μm. These HA-coated implants were designed to improve bone bonding by mimicking the mineral content of bone.
HA coatings, especially plasma-sprayed ones, can delaminate from the implant surface over time due to poor adhesion to the titanium substrate. This can lead to inflammation or failure of the implant
However, HA coatings are now less common due to challenges with long-term stability.[18]

Titanium Plasma Sprayed (TPS, ITI):
ITI (International Team for Implantology) was the company that used titanium plasma spray (TPS) technology for implant surfaces. The TPS method was designed to enhance the surface roughness which ranged between 5 to 7 μm, to promote better osseointegration, although this was later superseded by the SLA method.
Titanium Plasma-Sprayed (TPS) coatings have become less commonly used in dental implants due to their relatively poor long-term stability and potential issues with coating delamination. The rough surface, while providing mechanical interlocking, can also lead to weak adhesion between the coating and titanium substrate, reducing the implant's overall durability.[18]

TiUnite (Anodized Surface, Nobel Biocare):
The surface of Nobel implants undergoes advanced treatments to optimize tissue integration. The TiUnite surface, for instance, is created through anodization, which increases the surface's roughness and oxide layer thickness. This moderately rough surface enhances early bone-to-implant contact, promoting better osseointegration. Another innovation, the TiUltra surface, combines varying levels of roughness with enhanced surface chemistry to improve hydrophilicity and tissue compatibility, supporting both soft and hard tissue integration. This multi-zonal design transitions from minimally rough near the collar to moderately rough near the apex, ensuring effective interaction with different types of bone.[18]

Osseotite (Acid-Etched Surface, BioHorizons):
BioHorizons adopted the Osseotite surface treatment, which involves a dual acid-etching process to create a roughened surface. It is designed to enhance bone-to-implant contact while minimizing the risk of peri-implantitis by maintaining a smooth top portion.[18]

SLA (Sandblasted Large-grit Acid-etched):
Straumann implants are primarily made from Roxolid, a proprietary titanium-zirconium alloy, and zirconia for specific applications like the PURE Ceramic Implant line. Roxolid® is specifically designed to enhance strength and reduce invasiveness by allowing the use of smaller implants without compromising mechanical stability. Zirconia is used for its high biocompatibility and aesthetic properties, particularly in areas with high visibility.[18]

Regarding surface treatments, Straumann employs two main technologies:
SLA Surface Treatment: This technique involves sandblasting with large-grit aluminum oxide followed by acid etching with substances like hydrogen chloride. This creates a roughened surface, enhancing bone-to-implant contact (BIC).

Research by Cochran et al. and others show that SLA surfaces improve osseointegration and reduce bone resorption compared to smoother surfaces. Long-term success rates for SLA implants are high, ranging between 97-100%, with follow-ups extending up to three years.
SLActive Surface Treatment: SLActive builds upon the SLA process but introduces a hydrophilic, chemically active surface. This is achieved by storing the implants in an isotonic saline solution to maintain surface reactivity and processing under a nitrogen atmosphere to prevent contamination. [18]
Studies demonstrate that SLActive surfaces enhance protein adsorption, blood coagulation, and early osseointegration. These features are linked to faster healing and better initial stability compared to SLA implants.
Both SLA and SLActive surfaces are backed by extensive evidence, showing enhanced biological responses that improve implant success rates.

Company: Dentsply/Friedent.
Frialit-2 implants from Dentsply/Friedent use a grit-blasted and acid-etched surface, similar to SLA, but treated at a high temperature. They claim strong cell adhesion, though more studies are needed.

Tioblast and Osseospeed (Company: Astra Tech):
Tioblast: This surface treatment involves a combination of grit blasting and acid etching processes, creating a surface with micro-roughness that promotes better osseointegration. Tioblast is designed to improve bone healing by enhancing the surface's interaction with the surrounding bone. This surface treatment has been shown to offer increased stability and predictability in the early stages of implant healing.

Osseospeed: Developed by Astra Tech, Osseospeed takes it a step further by incorporating fluoride treatment on a micro-roughened titanium surface. The fluoride treatment is designed to create a unique nanoscale topography that accelerates bone healing and enhances bone-to-implant bonding. Studies have demonstrated that Osseospeed implants promote faster and stronger bone formation compared to conventional untreated surfaces. Additionally, it features MicroThread technology on the implant neck, optimizing load distribution and reducing stress at the bone-implant interface.
These advancements have transformed dental implants into a reliable, long-term solution for tooth replacement, pushing the boundaries of what's possible in dental restoration.[19]

A study by Rupp et al. (2006) focuses on enhancing the surface properties of titanium dental implants through chemical modifications. The research particularly examines the impact of increasing surface free energy and hydrophilicity on titanium implant surfaces to improve

osseointegration. The research supports the development of Straumann's SLActive implant surfaces, which are stored in an isotonic saline solution to maintain their hydrophilic properties. This advancement contrasts with the conventional SLA surfaces stored dry, emphasizing the improved wettability and faster healing times with SLActive surfaces.[20]

The study by Schwarz et al. (2008) examined how surface characteristics influence bone regeneration around dental implants in dehiscence-type defects, comparing Straumann SLActive implants with Biomet 3i NanoTite implants. Conducted on beagle dogs, the experimental study involved creating standardized defects and analyzing bone regeneration at intervals of 4 and 8 weeks.
The results demonstrated that SLActive implants achieved significantly higher bone-to-implant contact (BIC), greater new bone fill, and more extensive coronal bone growth compared to NanoTite implants. SLActive implants supported the formation of both trabecular and woven bone, resolving most defect areas by the 8-week mark. A key factor in this success was the stabilization of a blood clot at the time of placement, which is critical for osseointegration.
In contrast, NanoTite implants were associated with connective tissue formation rather than robust bone regeneration. The collapse of blood clots during healing was a frequent issue, impeding the regenerative process.
The study concluded that surface hydrophilicity, as observed in SLActive implants, plays a more critical role in bone regeneration than nanotopography. SLActive implants create a more favorable healing environment, making them especially beneficial for challenging clinical scenarios such as dehiscence defects
.[19]

Implant loading protocols define the timing and approach for attaching prosthetic restorations to dental implants after placement. These protocols are crucial for achieving optimal osseointegration and clinical success. There are three primary protocols:

Immediate Loading: The prosthesis is attached within 48 hours of implant placement. This approach often requires specific conditions, such as good primary stability (35–45 Ncm torque) and a controlled occlusal load. Immediate loading can improve patient satisfaction by reducing the treatment timeline, but careful case selection is required to minimize risks like micromovement of the implant during healing.

Early Loading: This protocol attaches the prosthesis between 1 and 12 weeks after implant placement. It offers a balance between reducing treatment time and allowing sufficient healing. Early loading is often used when primary stability is moderate, allowing partial osseointegration before functional loading.

Conventional (Delayed) Loading: The prosthesis is attached after a healing period of 3–6 months. This approach is the most conservative and is typically used when bone quality or

quantity is compromised or when high-risk factors for implant failure are present. It allows full osseointegration before applying functional forces to the implant.[21]

Implant-Supported Fixed Complete Dental Prostheses: An Overview

The field of implant dentistry has undergone significant advancements over the past few decades, greatly enhancing the treatment options available for edentulous patients. Among these innovations, implant-supported fixed complete dental prostheses (IFCDPs) have become a highly effective solution for full-arch rehabilitation. IFCDPs provide patients with a fixed, non-removable alternative to traditional complete dentures, improving their quality of life by enhancing their ability to eat, speak, and smile confidently.[21]

The development of IFCDPs has been driven by the pursuit of optimal esthetics, durability, and biocompatibility. While traditional materials such as metal-acrylic and metal-ceramic have been commonly used, each with its own advantages and limitations, the introduction of high-strength ceramics, particularly monolithic zirconia, has opened new possibilities for full-arch implant rehabilitation.

The evolution of IFCDPs represents a transformative shift in prosthodontics, especially for patients with complete edentulism. Initially, treatment options were limited to removable dentures, which often lacked sufficient retention and stability, particularly in cases with significant bone resorption. However, with the use of dental implants, the scope of rehabilitation has expanded from traditional single-tooth implants to full-arch fixed restorations, providing superior function and comfort compared to removable dentures. The introduction of innovative materials like zirconia and porcelain, along with improved surgical techniques, has significantly reduced complications and extended the longevity of IFCDPs.

As the demand for more esthetic and durable restorations continues to grow, monolithic zirconia has gained popularity as a material of choice for IFCDPs. This introduction aims to explore the current state of knowledge regarding implant survival and biological complication rates associated with monolithic zirconia IFCDPs, providing a comprehensive overview of the subject and highlighting the importance of ongoing research in this area.[22]

Overall, the shift from removable to fixed complete dental prostheses has enhanced the quality of life for many edentulous patients, and with ongoing innovations, the future of IFCDPs looks promising. For instance, studies on zirconia-based prostheses have reported survival rates of up to 100%, with most complications being restorable.

Moreover, digital technologies have revolutionized implantology. The integration of computer-aided design and manufacturing (CAD/CAM), as well as 3D printing, has allowed for more precise planning and implant placement, minimizing surgical invasiveness and improving

long-term outcomes. These innovations, including digital workflows and guided surgery, have significantly reduced complications and recovery times.

The future of implantology continues to evolve with the use of artificial intelligence (AI) in diagnosis and treatment planning, enhancing precision and outcomes. Furthermore, the exploration of bioactive and zirconia implants, particularly in esthetically demanding areas, continues to grow, offering patients more options tailored to both functionality and aesthetics.

When evaluating the success of metal-ceramic implant-supported fixed prostheses (IFPs), Wong et al. [23] discovered that the most common complication was the fracture of the veneering porcelain. This finding aligns with a retrospective study on metal-ceramic IFPs, , which reported a cumulative rate of 50.4% for "prosthesis free of biologic complications" at five years and 10.1% at ten years. Over the past decade, there has been an increase in the use of monolithic ceramic materials for IFPs,[24] resulting in reduced technical complications involving material chipping and fracture. Tischler et al. [25] demonstrated a cumulative survival rate of 96.8% over a four-year follow-up period for monolithic full-arch zirconia prostheses with veneered porcelain only in the gingival region, and minimal complications were observed. Barootchi et al. [23]reported that although zirconia IFCDPs have higher initial costs than metal-acrylic hybrids, they offer satisfactory outcomes, reduced overall complications, and superior survival rates.

Digital dentistry:

Digital dentistry has evolved significantly over the past few decades, revolutionizing various aspects of dental practice. Initially, dental procedures were mostly manual, involving traditional tools and methods for diagnostics and treatments. As technology advanced, there was a shift towards digital tools aimed at improving the accuracy and efficiency of dental procedures.
The earliest applications of digital technology in dentistry included the use of X-rays for imaging, which provided a more efficient and safer alternative to traditional radiographs. This led to the development of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) technologies in the 1980s, marking a major turning point. These technologies enabled the digital creation of dental restorations, allowing for more precise fitting of crowns, bridges, and dentures and dramatically reducing the time needed for their conventional ways of production.
In the following years, digital workflows expanded, incorporating tools such as intraoral scanners, which replaced the need for traditional impressions. This shift enabled more accurate, faster, and less uncomfortable patient experiences. The integration of Cone Beam CT (CBCT) scanning further advanced the field by providing 3D imaging that enhanced implant planning and other complex procedures like guided implant surgery.

In addition to improving diagnostic and treatment planning, digital dentistry has also impacted areas such as orthodontics, with 3D visualization of dental structures and final treatment outcomes becoming a new standard for treatment planning and execution.
The continued emergence of 3D printing and robotic surgery further pushes the boundaries of what digital dentistry can achieve, creating the potential for fully customized, precise treatments at a lower cost, fewer errors , and fewer patient visits.
This evolution has not only improved clinical outcomes but has also made dental education more accessible through online learning platforms and digital simulators, making it easier for practitioners to stay updated with cutting-edge techniques.
As digital dentistry continues to develop, its potential to transform patient care and dental practice is immense, pointing towards a future where most aspects of treatment will be driven by digital technologies.[26]

Digital dentistry offers transformative benefits that enhance both clinical processes and patient experiences. One significant advantage is time-saving: streamlined digital workflows, including chairside CAD/CAM systems, reduce the number of appointments needed for restorations like crowns and bridges, allowing for single-visit treatments. This efficiency extends to patient comfort, as digital impressions eliminate the need for traditional materials such as alginate or silicone, which many find uncomfortable. Intraoral scanners provide a quick, non-invasive experience, particularly beneficial for patients with gag reflexes or dental anxiety.
Improved communication is another key benefit. Digital tools facilitate seamless information sharing between dentists, labs, and patients. Scanned images and 3D models allow patients to visualize treatment plans, enhancing understanding and trust.
Accurate evaluation of tooth preparations is enhanced by high-resolution digital scans, which help identify undercuts or irregularities in real-time, ensuring precise restorations. Additionally, digital impressions maintain dimensional stability, unlike traditional impressions that may shrink or distort. This stability leads to better-fitting restorations and fewer errors. Digital impressions also eliminate common faults such as voids, drags, and tears, reducing the need for retakes and saving resources. If any data is missing during scanning, it can be easily recaptured and integrated without restarting the process, improving overall efficiency.
Efficient data storage and retrieval are integral to digital dentistry. Electronic records save physical space and simplify case documentation, future comparisons, and remote consultations.
Enhanced infection control is another benefit, as digital workflows minimize the need for physical models, reducing cross-contamination risks and supporting stringent safety protocols.
The stored digital data simplifies prosthesis replacement, as new restorations can be fabricated without additional impressions, ideal for cases of damage or wear. Finally, digital scans offer an excellent baseline for follow-up and monitoring, allowing dentists to track changes over time

accurately. This capability is particularly useful for monitoring tooth wear, periodontal health, and implant stability, ensuring comprehensive long-term care.

In contrast to digital dentistry, analog methods often involve labor-intensive and time-consuming procedures. Processes like taking physical impressions, pouring models, and handcrafting restorations are slow and typically require multiple appointments, increasing overall treatment time. This can lead to longer waiting periods for patients and a higher risk of errors. Manual methods are prone to inaccuracies such as distortion during impression-taking, improper model pouring, and difficulties in achieving precise fitting of restorations. These errors can result in delays, poorly fitting prosthetics, and the need for additional adjustments. [27]

Analog impressions are also subject to material shrinkage or deformation, which can cause discrepancies between the patient's anatomy and the final restoration. In contrast, digital methods offer greater accuracy, reproducibility, and less material-related distortion traditionally, physical models created using conventional methods require storage space in dental offices, leading to clutter and administrative challenges. Digital models, however, can be stored virtually, freeing up physical space.

Patient is another issue, as many patients find traditional impression-taking uncomfortable due to materials like alginate or silicone, which need to be held in place for extended periods. This discomfort can contribute to anxiety and reluctance to undergo dental procedures.[27]

Finally, upfront costs of analog tools may be lower than digital equipment, the recurring expenses for impression materials, labor, and storage add up over time. The analog process often results in more material waste and requires more labor, leading to higher long-term costs compared to digital workflows ..

The digital design and milling of zirconia for Implant-Supported Fixed Complete Dental Prostheses (IFCDPs) has undergone significant advancements due to the integration of CAD/CAM technologies. These innovations have enhanced the precision, efficiency, and aesthetic outcomes of prosthetic restorations, making zirconia a material of choice for full-arch rehabilitations.

Digitally designing zirconia involves using CAD software to model the prosthetic framework based on a 3D scan of the patient's dental anatomy. This allows for highly accurate designs with tailored fit and functionality. The milled frameworks are typically made from pre-sintered zirconia blanks, which are then sintered at high temperatures to achieve optimal strength and durability. This process can be customized to create monolithic zirconia prostheses, which are both functional and aesthetically pleasing, thanks to the translucency of newer zirconia formulations [25-27].

The milling process, using advanced computer-controlled machines, ensures a high level of accuracy in producing these prostheses. This minimizes common issues found in traditional methods, such as gaps or fitting inconsistencies between the implant and prosthesis. Additionally, CAD/CAM technologies offer the ability to create permanent digital files, which can be used to duplicate prostheses if necessary, improving both the longevity and efficiency of patient care. [28]

Overall, the integration of digital technologies has revolutionized the design and fabrication of zirconia-based IFCDPs, providing enhanced precision, strength, and aesthetic results with improved patient satisfaction and reduced complications.

Dr. Papaspyridakos and his colleagues have contributed extensively to understanding the advantages of digital workflows in implant dentistry, particularly in the fabrication of Implant-Supported Fixed Complete Dental Prostheses (IFCDPs). In comparison to traditional analog methods, digital fabrication offers notable improvements in precision and clinical outcomes, particularly in the context of implant impressions and prosthesis design.[29]
The digital fabrication of IFCDPs offers significant clinical and operational advantages, including greater precision, reduced chairside adjustments, and improved prosthesis longevity. However, the decision to use digital or traditional methods may still depend on factors like the complexity of the case, the equipment available, and the clinical expertise of the practitioner .[28]

Why zirconia is the material of choice:[30]

There are three main types of dental porcelains:

Predominantly Glassy Materials:These ceramics primarily consist of silica (silicon oxide) and alumina (aluminum oxide) derived from feldspar. Modifying agents, such as sodium (Na^+) and potassium (K^+), are incorporated to adjust thermal expansion and lower firing temperatures. They offer exceptional aesthetics due to their excellent translucency and optical properties, closely mimicking natural teeth. However, they lack significant crystalline reinforcement, resulting in lower mechanical strength. Dicor was the first commercially available glass ceramic enhanced with 55% crystalline mica filler to improve mechanical properties.
It is ideal for anterior restorations where aesthetics are crucial and functional loads are minimal.

Particle-Filled Glasses:These materials combine a glass matrix with crystalline fillers, such as leucite or lithium disilicate, to enhance both strength and aesthetics.
Characteristics: They are stronger than predominantly glassy ceramics due to the reinforcing crystalline phase. These materials offer versatility as they can be used for standalone restorations or veneered over metal frameworks. While their aesthetics are moderate compared to glassy ceramics, they provide a good balance between strength and appearance.

Leucite-based ceramics are often used for veneering metal frameworks due to their compatible thermal expansion. Pressed ceramics, like Empress and Finesse All-Ceramic, combine strength and aesthetics, making them suitable for single crowns, veneers, and anterior bridges.

Polycrystalline Ceramics:These ceramics are nearly entirely crystalline with minimal glass content. They include materials such as alumina and zirconia, which are known for their dense, structured arrangement.

Polycrystalline ceramics are significantly stronger than glass-based types due to their resistance to crack propagation. Zirconia, for example, has twice the fracture toughness of alumina. However, their opacity limits aesthetic appeal compared to glass-based ceramics.

Fabrication requires precise machining, and they undergo considerable shrinkage during firing (approximately 30% volumetric and 10% linear).

They are primarily used as high-strength substructures in posterior restorations. For anterior use, they are often veneered with more aesthetic ceramics to enhance their appearance.

The emergence of zirconia as a preferred material for implant-supported fixed complete dental prostheses (IFCDPs) is a result of continuous advancements in materials science and engineering. Initially, zirconia was mainly used in its traditional tetragonal form (3Y-TZP), known for its strength but limited translucency. However, ongoing research has led to the development of more translucent and durable zirconia options, particularly in the form of 5Y-TZP and 4Y-TZP, which offer superior aesthetics and mechanical properties.

The development of monolithic zirconia, which does not require additional veneering ceramics, has further solidified its role in prosthodontics, especially for single crowns and multi-unit restorations. This material has shown excellent fracture resistance and long-term durability, making it a viable option for the demanding conditions of implant-supported prostheses.

Moreover, innovations such as surface treatments and aging protocols have improved the material's performance, enhancing its bonding properties and resistance to wear. The increased translucency of newer zirconia formulations allows for more natural-looking restorations without compromising strength, which is particularly beneficial in the anterior region where aesthetic considerations are critical.

In clinical practice, zirconia's adaptability for both anterior and posterior restorations, combined with its minimal wear on opposing teeth, has made it an increasingly popular choice for IFCDPs. Additionally, ongoing research into the optimal surface treatments and cementation protocols continues to enhance its clinical outcomes.

Zirconia materials have evolved through four distinct generations, each tailored to meet specific functional and aesthetic demands in dental restorations. The first generation, composed of 3 mol% yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP), is characterized by its exceptional flexural strength (900–1200 MPa) and fracture resistance. However, its high alumina content (0.25%) and the dominance of the tetragonal crystal phase result in low

translucency, making it ideal for posterior crowns and bridges where strength is prioritized over aesthetics. Second-generation zirconia retained the robust properties of 3Y-TZP while slightly reducing the alumina content to achieve moderate translucency. With flexural strength between 800–1000 MPa, this generation is suited for posterior monolithic crowns.
The third generation marked a significant shift, introducing 4 mol% yttria-stabilized zirconia (4Y-TZP). This composition incorporates more cubic phase crystals (~25%), which reduces light scattering and enhances translucency while maintaining adequate strength (600–800 MPa). This generation also exhibits greater resistance to aging and hydrothermal degradation, making it suitable for anterior and posterior monolithic restorations requiring improved aesthetics.
Finally, the fourth generation, composed of 5 mol% yttria-stabilized zirconia (5Y-TZP), is optimized for high aesthetic demands. With a cubic phase dominance (~50%), this material achieves translucency comparable to lithium disilicate and natural enamel. Although its flexural strength (500–600 MPa) is lower than previous generations, it is sufficient for anterior teeth and single-unit posterior restorations, making it ideal for highly aesthetic applications such as monolithic crowns, veneers, and anterior restorations. This progressive development reflects the dynamic balance between strength and translucency in zirconia materials, catering to diverse clinical needs

The evolution of zirconia generations has been marked by a continuous balance between strength and translucency to suit a wide range of dental applications. First-generation zirconia, with 3 mol% yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP), is known for its high flexural strength (900–1200 MPa) but limited translucency, resulting in an opaque appearance. This makes it ideal for posterior frameworks and veneered crowns, where strength is more critical than aesthetics. The second generation, also composed of 3Y-TZP, reduced the alumina content slightly, achieving a moderate improvement in translucency while maintaining a flexural strength of 800–1000 MPa. This generation is well-suited for posterior monolithic crowns where durability and moderate aesthetics are required.
The third generation, featuring 4 mol% yttria-stabilized zirconia (4Y-TZP), introduced a significant enhancement in translucency by incorporating cubic phase crystals (~25%) that reduce light scattering. Although the strength is slightly reduced (600–800 MPa), this material is widely used for anterior and posterior monolithic crowns due to its balance of aesthetics and performance. Finally, the fourth generation, with 5 mol% yttria-stabilized zirconia (5Y-TZP), prioritizes aesthetics with a dominance of cubic phase crystals (~50%), achieving translucency comparable to natural enamel. While its flexural strength is reduced to 500–600 MPa, it is sufficient for single-unit anterior crowns, veneers, and other highly aesthetic restorations. These advancements, supported by studies such as Zhang et al. (2019) and Sulaiman (2020), reflect the evolving priorities in zirconia materials to address diverse clinical requirements.[31, 32]

Zirconia sintering is a high-temperature process that transforms pre-sintered zirconia into a fully dense and durable material suitable for dental and medical applications. Initially, zirconia

is milled in its soft, partially sintered state, making it easier to shape. The material is then heated in a sintering furnace at temperatures between 1,450°C and 1,600°C. During this process, the zirconia particles fuse, reducing porosity and increasing density, resulting in a strong and highly durable final product. The sintering process occurs in stages, starting with the bonding of particle surfaces, followed by further densification as pores shrink, and finally achieving near-complete density.

Several factors influence the quality of sintered zirconia, including temperature, time, atmosphere, and material composition. Higher temperatures and optimized sintering durations enhance strength and translucency, while additives like yttria stabilize the material's structure. Sintered zirconia exhibits exceptional fracture toughness, resisting crack propagation due to its transformation mechanism. Its strength, hardness, and improved translucency make it ideal for aesthetic dental applications. However, the process causes approximately 20-25% shrinkage, requiring precise adjustments during milling. Sintered zirconia is widely used for crowns, bridges, and implant components, offering excellent biocompatibility, aesthetics, and durability.[33]

The digital fabrication of zirconia dental restorations, particularly for implant-supported fixed complete dental prostheses (IFCDPs), has become increasingly efficient and precise. Digital workflows involving CAD/CAM technology eliminate many traditional manual steps, such as waxing and casting, resulting in faster production times and reduced human error. Monolithic zirconia, in particular, benefits from this digital fabrication process, as it can be designed with high accuracy, reducing the need for additional layering or veneering materials This has not only improved the consistency and fit of restorations but also allowed for more predictable outcomes in both strength and aesthetics. [33, 34]

There are two types of complications associated with IFCDPs:

1. Technical or Mechanical Complications:

These involve issues related to the physical structure and materials of the prostheses, affecting their integrity and function.

2. Biological Complications:

These involve issues related to the biological response of tissues surrounding the implants and prostheses.22

Technical or Mechanical Complications, such as Framework fractures, are rare in metal-ceramic IFCDPs due to the strength of metal frameworks.

Ceramic chipping is also a common issue, although less frequent than with zirconia-based prostheses. Chipping may affect aesthetics but is usually repairable without requiring replacement.[35]
Abutment or screw issues include abutment screw loosening and, occasionally, screw fractures. These can compromise prosthesis stability and may require maintenance.
Loss of retention, reported primarily in cement-retained prostheses, involving detachment from the supporting structure, though less common in complete-arch prostheses compared to smaller FDPs.

Biological Complications such as Peri-implantitis and soft tissue issues:
Inflammation around the implant sites, including mucosal complications. These issues are more prevalent in patients with poor oral hygiene or systemic conditions.
Marginal bone loss: Some bone loss is expected over time, but significant loss (beyond normal remodeling) could compromise implant stability and long-term success.[35]

The study by Ignacio Gonzalez-Gonzalez et al. examines the complications associated with fixed full-arch implant-supported metal-ceramic prostheses (IFCDPs) over a five-year period. These complications are classified into biologicaland mechanical-technical categories.
Biological Complications: Mucositis was the most frequently reported biological issue. Peri-implantitis affected 13.8% of restorations and 16.9% of patients, with a lower occurrence (2.0%) at the implant level.An implant length of more than 10 mm was identified as a protective factor against these biological complications, reducing the likelihood of soft tissue issues.
Mechanical-Technical Complications: The most common issue was the loss of screw access filling, which if not fixed, can affect stability.
Porcelain fractures were another significant complication, impacting aesthetics and functionality but were less frequent compared to other mechanical issues.
Factors such as implant diameter, the abutment-implant connection, and the retention system were associated with these mechanical problems.
Survival Rates:
The study reported high survival rates: 99.8% for implants and 98.8% for prostheses, indicating overall reliability despite the noted complications. Regular maintenance and monitoring are essential to manage these issues effectively.[36]

The article identifies various complications associated with complete-arch implant-supported monolithic zirconia fixed dental prostheses. Mechanical complications include prosthetic denture tooth or ceramic chipping, which was reported in two studies, along with abutment fractures and framework fractures. Additional issues involve loose abutments, debonding components, and catastrophic failures where the entire zirconia structure failed. Although screw loosening or fracture is a known complication with metal-acrylic prostheses, it was not specifically highlighted for zirconia in the reviewed studies. Some reports also

mentioned challenges related to phonetics and masticatory function, though detailed data was limited. Despite these complications, the short-term survival rate was high at 96.8%, underscoring the need for more comprehensive long-term studies to assess the overall performance and reliability of monolithic zirconia prostheses.

Biological complication definition;

Peri-implantitis is an inflammatory condition that affects both the soft tissues and bone surrounding a dental implant, leading to infection and bone loss. It typically occurs due to bacterial infection, often resulting from poor oral hygiene or inadequate cleaning around the implant. Other causes include incorrect implant placement, which can result in plaque accumulation; smoking, which impairs healing; and excessive mechanical loading or pressure on the implant. The effects of peri-implantitis include soft tissue inflammation, pain, redness, swelling, and significant bone loss around the implant. If left untreated, it can lead to implant failure. Timely intervention is crucial to prevent these adverse outcomes.[37]

Peri-implant mucositis is a reversible inflammatory condition that affects only the soft tissues surrounding a dental implant without causing bone loss. It is often considered a precursor to peri-implantitis if left untreated. The primary causes of peri-implant mucositis include poor oral hygiene, leading to plaque buildup, as well as failure to properly clean the implant or surrounding tissues. Smoking and poor systemic health can also contribute to the condition. The effects of peri-implant mucositis include redness, swelling, and bleeding of the gums around the implant, accompanied by mild discomfort or pain. While there is no bone loss at this stage, untreated mucositis can progress to peri-implantitis, which may result in more severe consequences, including bone loss.[37]

Implant mobility refers to the loosening or instability of a dental implant, which can occur when the implant fails to properly integrate with the surrounding bone or due to other underlying complications. The primary causes of implant mobility include poor osseointegration, where the bone fails to properly bond with the implant, insufficient bone volume or quality to support the implant, overloading or excessive forces placed on the implant, and infection or inflammation around the implant. The effects of implant mobility include a loss of implant stability, which can lead to functional problems such as discomfort or pain when chewing or applying pressure. If left unresolved, it may result in the need for implant removal or replacement.[38, 39]

Bone loss around a dental implant refers to the resorption or deterioration of the bone that supports the implant, which can occur due to factors such as infection, mechanical overload, or poor osseointegration. The primary causes of bone loss include peri-implantitis and other infections, mechanical overload from excessive forces on the implant, poor initial osseointegration, and systemic conditions like osteoporosis, diabetes, or smoking. The effects of

bone loss include decreased implant stability and an increasing risk of implant failure. Aesthetic concerns may also arise if the bone loss is visible around the implant site, and in severe cases, it may require bone grafts or other surgical interventions to restore the bone and improve implant stability.[38]

Soft tissue recession refers to the loss of gum tissue around a dental implant, which can expose the implant surface and create aesthetic concerns. The primary causes of soft tissue recession include surgical trauma or improper implant placement, infection or inflammation such as peri-implantitis, excessive forces on the implant or surrounding tissue, and inadequate soft tissue management during the implant procedure. The effects of soft tissue recession include the exposure of the implant surface, leading to aesthetic issues, sensitivity to temperature and pressure, and an increased risk of infection as the exposed implant surface becomes more susceptible to bacterial accumulation. Managing soft tissue health is crucial to maintaining implant stability and aesthetics.[40]

Probing depths are also measured using a periodontal probe, with increased depth and bleeding on probing (BOP) indicating potential inflammation or infection. Radiographic evaluations, such as periapical or panoramic X-rays, are essential for assessing bone levels around the implant. A significant vertical bone loss of more than 2 mm is indicative of peri-implantitis. Comparing current radiographs with baseline images helps in tracking changes over time. Additionally, microbiological testing can help identify pathogens linked to peri-implant disease, although it is generally not routine unless the condition is persistent or refractory. In some cases, more advanced diagnostic methods, such as peri-implant sulcus fluid analysis or cone-beam computed tomography (CBCT), may be used to detect specific biomarkers or visualize detailed bone changes. It is important to distinguish between peri-implant mucositis, which is reversible and limited to soft tissue inflammation, and peri-implantitis, which is irreversible and involves bone loss. Regular monitoring and early intervention are critical to prevent disease progression and ensure the longevity of the implants.[40]

The plaque index is closely associated with peri-implantitis as it measures the accumulation of bacterial plaque around dental implants, a primary factor in the development of peri-implant diseases. High plaque index scores indicate poor oral hygiene, which leads to the formation of bacterial biofilms. These biofilms trigger inflammation in the soft tissues (peri-implant mucositis) and, if untreated, progress to peri-implantitis, causing bone loss and potential implant failure.

Research highlights that maintaining low plaque levels is crucial for preventing peri-implantitis. For instance, a study showed that patients with poor plaque control had a significantly higher risk of peri-implantitis compared to those maintaining proper hygiene. The presence of plaque correlates directly with increased bleeding on probing, deeper probing depths, and progressive bone loss around implants.

Effective oral hygiene practices, regular professional cleanings, and early intervention in cases of plaque accumulation are essential strategies to mitigate this risk. [41, 42]

There are several factors may influence the incidence of biological complications in monolithic zirconia IFCDPs:

Material properties: Zirconia's smooth surface and low plaque affinity may contribute to reduced bacterial adhesion compared to other materials.

Prosthesis design: The contours and emergence profile of the prosthesis can impact plaque accumulation and tissue health.

Implant-abutment connection: The type of connection and its ability to prevent bacterial leakage may influence peri-implant health.

Cement-retained vs. screw-retained designs: The choice of retention method can affect the risk of residual cement and associated complications.

Patient factors: Oral hygiene, smoking, systemic health conditions, and genetic susceptibility play crucial roles in the development of peri-implant diseases.

Maintenance protocols: Regular professional care and patient compliance with home care instructions are essential for preventing and managing complications.

Implant survival is a critical factor in evaluating the long-term success of IFCDPs. While extensive literature exists on implant survival rates for various prosthetic materials, studies specifically focused on monolithic zirconia IFCDPs are still emerging. However, initial reports suggest promising outcomes.

Several factors can influence implant survival rates in the context of monolithic zirconia IFCDPs:

1. Implant design and surface characteristics: Modern implant systems with improved designs and surface treatments may contribute to enhanced osseointegration and long-term stability.
2. Surgical technique: Proper implant placement and adherence to surgical protocols are crucial for initial stability and long-term success.
3. Loading protocols: The timing and method of prosthetic loading can impact implant integration and survival.
4. Patient-related factors: Systemic health conditions, smoking habits, and oral hygiene practices can affect implant outcomes.
5. Prosthesis design: The distribution of occlusal forces and the passive fit of the prosthesis play important roles in implant longevity.

The article Do Systemic Diseases and Medications Influence Dental Implant Osseointegration and Dental Implant Health? [43]
An Umbrella Review explores the impact of systemic diseases and medications on dental implant outcomes, including osseointegration, implant success and survival rates, peri-implant health, and implant loss. The review synthesizes data from eight systematic reviews, primarily investigating conditions like osteoporosis and diabetes.

Key findings indicate that most systemic diseases, such as cardiovascular conditions, neurological disorders, HIV, and hypothyroidism, do not significantly impair implant osseointegration. Similarly, common medications, including beta blockers, anti-hypertensives, and diuretics, show no adverse effects. However, certain drugs like proton-pump inhibitors (PPIs) and serotonin reuptake inhibitors (SSRIs) are associated with negative impacts on osseointegration. While hyperglycemia in diabetic patients is linked to a higher risk of peri-implantitis, it does not necessarily increase the risk of peri-implant mucositis.[43]

Bain and Moy (2005) concluded that while the overall failure rate of dental implants remains low, certain risk factors—such as smoking, diabetes, radiation therapy, and postmenopausal women on HRT—significantly increase the likelihood of implant failure. These findings highlight the need for thorough patient evaluation and management of risk factors before implant placement to ensure the best possible outcomes.

Risk Factors for Increased Failure Rates:

Smoking: Smokers have a significantly higher risk of implant failure due to reduced blood flow, impaired healing, and increased risk of infection, particularly peri-implantitis.

Diabetes: Diabetic patients, particularly those with poorly controlled blood sugar levels, are at a higher risk of implant failure due to impaired healing, increased susceptibility to infection, and reduced bone quality.

Radiation Therapy (Head and Neck): Patients who have received radiation therapy to the head and neck area are at a higher risk of implant failure. Radiation damages bone density and blood supply, impairing the osseointegration process.

Postmenopausal Women on Hormone Replacement Therapy (HRT): Postmenopausal women on HRT may experience a higher risk of implant failure due to changes in bone density. Although HRT can reduce bone loss, it does not entirely eliminate the risk of bone-related complications that affect implant stability.[43]

The reviewed study by Celleti, Asikainen, and Miyata explores the impact of non-axial loading (i.e., forces applied at an angle to the implant rather than directly along its axis) on the integration of dental implants. The key findings suggest:

Non-axial loading, even when exaggerated, does not significantly hinder the osseointegration (bone-implant integration) process. This means that applying occlusal forces at angles to the implant axis does not prevent the bone from properly fusing with the implant surface. Even when the magnitude of non-axial forces is significantly increased, the studies showed that these forces do not have a detrimental effect on implant stability or osseointegration. This challenges earlier views that suggested misaligned forces could lead to implant failure or reduced integration.

Implant Design and Load Distribution: The findings could be beneficial in understanding how implants can be designed and placed with more flexibility in terms of occlusal force direction. It opens possibilities for patients with complex occlusions or functional loading patterns, suggesting that non-axial forces may not require as much concern as previously thought.

This research may impact how clinicians approach implant placement and occlusal design. Since exaggerated non-axial forces do not appear to impair integration, there could be more room for accommodating various patient behaviors or dental conditions without compromising the implant's success.

However, the use of angled abutnent has advantages such as:

Ease of Prosthesis Handling: Working at the abutment level simplifies the prosthesis design and handling process, reducing the complexity of seating the restoration compared to directly working at the implant level.[44]

Reduced Risk of Peri-implantitis: Abutment-level connections may help in reducing the risk of peri-implantitis by limiting the disturbance by bringing implant-abutment interface away from bone, potentially minimizing microbial leakage.

Improved Soft Tissue Management: Abutment-level restorations offer better control over soft tissue healing and maintenance, leading to enhanced esthetic outcomes, especially when using materials like zirconia.

Enhanced Access for Maintenance: Cleaning and maintenance are often easier with abutment-level prostheses, as the prosthesis can be removed without disturbing the implant itself

Corrects angulation: In the case of a tilted implant, companies offer different abutment angulation to correct non-ideal implant angulation.

These are some of the reasons Why we prefer abutment abutment-level restorations.54

In a systematic review in 2012, Papaspyridakos et al. [35]
reported that biological and technical complications routinely occur with implant-supported fixed complete dental prostheses (IFCDPs). Nowadays, the number of edentulous patients is steadily increasing, and so is the use of dental implants. [45-48]To effectively inform patients about treatment options and their potential risks and benefits, clinicians must be familiar with the frequency, nature, and occurrence rate of complications associated with each treatment

method. This ensures evidence-based information can be presented to patients, allowing them to make informed decisions regarding their treatment.

The outcome and survival rates of implant-supported prostheses have been reviewed in several studies, demonstrating survival rates between 85 and 99% over the years [7, 45, 49, 50]. Widespread use of implant-supported prostheses has led to increasing complications over 3 years of service of the prostheses. Despite the inability to compute a comprehensive incidence rate for complications in implant prostheses, existing research indicates a higher occurrence of clinical complications compared to other types of restorations.[10, 24, 26, 38, 46, 51] Two types of complications can be observed in implant dentistry: technical and biological. Technical complications encompass mechanical damage to implants, implant components, and prostheses. [35] Although these complications may not necessarily lead to complete implant loss, they can increase the need for repairs and maintenance sessions. Only a few studies have quantitatively assessed the costs associated with the maintenance and repair needs of implant-supported fixed dental prostheses (IFCDPs). [52, 53] On the other hand, biological complications result from the biological process that affects the peri-implant tissue and ultimately interferes with implant function, leading to implant loss and inflammation of the peri-implant tissue. [36-38, 47, 54-56]In order to properly diagnose these complications, Common related peri-implant tissue diseases include soft tissue hyperplasia, hypotrophy, peri-mucositis, and peri-implantitis [57]. A systematic review of implant-supported fixed dental prostheses (FDPs) by Pjetturrson et al.[28] showed that the survival rate of rough implants was 97.2% after five years. The survival rate of implant-supported FDPs was 95.4% after five years and 80.1% after ten years of function. The survival rate increased significantly when the analysis was done exclusively for metal-ceramic FDPs, and gold-acrylic FDPs were excluded. The survival rate of metal-ceramic implant-supported FDPs was 96.4% after five years and 93.9% after ten years. The most frequent biological complications over the 5-year observation were peri-implantitis and soft tissue complications (8.5%), and only 66.4% of the patients were free of any complications after five years. The increased technical complications in the case of metal acrylic and metal-ceramic prostheses have nowadays led to zirconia being the predominant material of choice for these implant reconstructions; this has led to significant improvement in performance over time with much less required maintenance and needs for repair or replacement of the prosthesis.

A meta-analysis conducted by Kern et al. [8] aimed to assess implant loss in edentulous jaws with implant-supported prostheses, considering factors such as prosthesis type (removable or fixed) and implant location (maxilla or mandible), among others. Out of the 54 studies included in the qualitative analysis, it was found that implant-fixed prostheses (IFCDPs) had a lower risk of implant loss per year compared to implant-overdentures (IODs) (0.23 vs. 0.35). Additionally, implant loss rates were significantly lower in the mandible compared to the maxilla (0.22 vs. 0.41). However, caution should be exercised in interpreting these results since most of the data

came from single-arm cohort studies, and there is a lack of well-designed comparative studies (RCTs). Although implants demonstrated a 5-year survival rate of 97.9% in the maxilla and 98.9% in the mandible, the influence of implant length, diameter, and distribution was not evaluated. These factors can potentially have a significant impact on the long-term prognosis depending on the type and design of the prosthesis. These findings partially align with a previous review by Bryant et al. [58], which indicated a 6.6% higher implant survival rate for mandibular IFCDPs than maxillary IFCDPs. Still, the variation across different established types of implant prostheses may have little effect.

In a systematic review by Papaspyridakos et al., [35] an implant-related biologic complication of peri-implant bone loss (> 2 mm) was at rates of 20.1% after five years and 40.3% after ten years. The most frequent prosthesis-related biological complication was hypertrophy or hyperplasia of tissue around the IFCDPs (13.0% after 5 and 26.0% after 10 years, respectively). In a retrospective study by the same author, [45][13] out of a total of 457 rough surface dental implants that supported 71 implant-fixed complete dental prostheses (IFCDPs) in 52 patients, only six implants failed. An average observation period of 5.2 years and an implant survival rate of 98.7% after inserting the definitive prosthesis were found. The most common minor biologic complications observed were soft tissue recession (7.7% per year), followed by inflammation under the IFCDP (7.4%), and peri-implant mucositis (6.3%). The most frequent major biologic complications were peri-implantitis (2.0% per year) and late implant failure (0.3%). Noteworthy, there were no significant differences in the frequency of biological complications between different restorative materials: metal ceramic and metal acrylic.

The longevity of dental implants can be compromised by the occurrence of biological complications. In fact, peri-implantitis has been regarded as the dominant reason for implant failure. Periimplant diseases are biofilm-mediated inflammatory conditions characterized by tissue breakdown. Predisposing factors such as:

Soft tissue substrate, If the Keratinized mucosa around the implant is less than 2 mm. will cause More discomfort during brushing, inflammation and potential mucosal recession. Attached keratinized gingiva is beneficial in patients with neglected oral hygiene; whereas patients with adequate oral hygiene measures may not benefit from attached keratinized gingiva. In addition, it must be noted that the lack of KM has been associated with a shallow vestibulum.

A shallow vestibulum is also a factor; if the depth of the vestibule is less than 4 mm, there is poorer access for plaque control measures and mobile mucosa.

18 This condition may hamper the access to achieve an adequate plaque control and may further contribute to deepen the peri-implant pocket, which in turn, may increase the colonies of anaerobic pathogenic bacteria.

Recent data demonstrated, however, that the presence of >2 mm of KM is associated with reduced plaque and bleeding scores, mucosal recession, patient discomfort, and bone loss.

Thin crestal phenotype also plays a major role in implant survival, if it if less than 2mm, More physiological/early bone resorption and mucosal recession is more likely to occur.[40]

Monje & Blasi demonstrated that on erratic compliers (<2/year), on comparing a KM band of <2 mm versus ≥2 mm.23 All the clinical and radiographic parameters were significantly increased when the KM band was <2 mm. It was further demonstrated that erratic compliers are about ten more exposed to peri-implantitis whenever the band of KM was <2 mm when compared to the same cohort of patients with ≥2 mm of KM at the buccal aspect.

The lack of attached KM in patients with inadequate oral hygiene could be regarded as a predisposing factor for peri-implant diseases since it is associated with more mucosal recession, more discomfort, lesser vestibular depth, and more plaque accumulation, which in turn may predispose to inflammation. [59]

Hard tissue substrate: In cases with Highly dense bone, More physiological/early bone resorption is more likely to occur.

It has been demonstrated that excessive compression triggered by the achievement of high primary stability may lead to 22%–50% more crestal bone loss than conventional implantation and also to a 41% reduction in the amount of bone-to-implant contact.

This results in weak bones that might not guarantee secondary stability. A multiscale analysis unveiled that the promotion of high primary stability (>50 Ncm) might further lead to a double layer of osteocyte necrosis that could jeopardize the process of osseointegration and peri-implant bone stability. [60]

On a clinical basis, Simons and colleagues demonstrated that in alveolar ridges that consist of <30% of cancellous bone (where higher primary stability is expected), bone loss tended to be greater at 3–4 years when compared to recipient implant bed consisting of>60% of cancellous bone. 46 Hence, interventions that endeavor at increasing primary implant stability are discouraged as it might lead to greater peri-implant bone loss that could predispose to peri-implant disorders after function. [61]

Surgical factor: Inadequate implant position can cause more buccolingual and/or vertical bone resorption.

High insertion torque (>50 Ncm) can cause more physiological/early bone resorption.

It is important to point at the surgical phase that the inadequate apico-coronal position of the implant may further contribute to the development of deep pockets that subsequently may be colonized by pathogenic bacteria. Along these lines, it is important to note that implant position should be dictated by the emergence profile rather to the existing alveolar bone. [60]

Recent data demonstrated, however, that the presence of >2 mm of KM is associated with reduced plaque and bleeding scores, mucosal recession, patient discomfort, and bone loss.

When an implant is inserted with an open-flap approach, the elevation of the periosteum eliminates the periosteal blood supply from the outside. The same process occurs from the inside, since insertion of the implant interrupts the endosteal blood supply. This phenomenon is described as "avascular necrosis" 29 and this concept has been recently demonstrated in vivo. As such, the critical buccal bone thickness for preventing significant physiological buccal-lingual bone resorption should not be less than 1.5 mm.
Along these lines, the apico-coronal implant positioning might further dictate the long-term stability of the peri-implant tissues. Based on the hypothesis that too-apical implant positioning may favor a longer epithelial barrier that might lead to the establishment of a microbial pathogenic environment. [60]

The 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions listed implant mal-positioning as a local factor associated with peri-implantitis due to limited access to perform oral hygiene measures.
following critical assessment by a group of experts in the field, agreed that >40% of the implants diagnosed with peri-implantitis presented with a "too-buccal position," [60]

Kumar and colleagues in non-splinted single implants demonstrated that implant placement at a depth of ≥6 mm from the cementoenamel junction of the adjacent teeth is more commonly associated with peri-implantitis (OR = 8.5).[62]
it is worth mentioning that this is only applicable to prosthetic structures supported by bone-level implants with no trans-mucosal abutment. In this sense, an implant position that is too shallow may lead to convex emergence profiles, which in turn are more liable to impact food debris and, thus, more prone to infection. Furthermore, the mesiodistal implant position could be regarded as a predisposing factor for peri-implant bone loss, leading to peri-implantitis due to two main factors: (1) Inadequate access for performing personal-administered oral hygiene measures and (2) excessive physiological bone remodeling if no safety distance is ensured between two dental implants or one implant with the adjacent tooth. Classically, the recommendation was to have 3 mm between dental implants.
Inadequate 3-dimensional implant position may predispose to greater physiologic bone loss or to the establishment of an anaerobic ecosystem within the peri-implant pocket. Moreover, it may promote inadequate prosthesis design that may preclude adequate self-performed oral hygiene measures. Hence, implant position may predispose peri-implant diseases.

Prosthetic factors: Inadequate emergence profiles to satisfy esthetic demands may lead to biological complications due to direct irritation to the mucosa and to the lack of access to self-performed oral hygiene measures. Could be attributed to deficient access for personal oral hygiene. It was shown, therefore, that 48% of the implants presenting peri-implantitis were those with no accessibility/capability for proper oral hygiene (65% positive predictive value) with respect to 4% of the implants with accessibility/capability (82% negative predictive value). 78% lacked adequate access to perform oral hygiene.[31]

For single- and multiple-crowns supported by bone-level implants with an emergence angle of over 30 degrees and a convex profile (over-contoured) have been shown to be factors significantly associated with peri-implantitis49, which is not applicable for tissue-level implant. In other words, crown margins positioned ≤1.5 mm from the bone at baseline are at increased risk of developing peri-implantitis (OR = 2.3).52 In fact, bone-level implants with transmucosal abutments have been shown to prevent/minimize excessive bone loss that might impair implant longevity.[60]

This study by Dr. Lindquist analyzed the impact of smoking and related factors on peri-implant bone loss in 45 edentulous patients over 10 years. It found minimal bone loss (approximately 1 mm) overall but greater loss in smokers, correlating with cigarette consumption and worsened by poor oral hygiene. In non-smokers, oral hygiene had a negligible effect. Multivariate analysis identified smoking as the primary factor influencing bone loss, with oral hygiene being a secondary contributor among smokers. Occlusal loading and other factors played a lesser role. The findings emphasize the importance of considering smoking habits in implant prognosis.

The article "Consensus Statements and Clinical Recommendations for Prevention and Management of Biologic and Technical Implant Complications" outlines evidence-based strategies for addressing complications in implant dentistry. Biologic complications, such as peri-implant mucositis and peri-implantitis, are emphasized, with recommendations focusing on prevention through periodontal therapy, proper oral hygiene, and adherence to supportive periodontal therapy (SPT). These measures significantly reduce the risk of implant failure, especially in patients with a history of periodontal disease. Management of peri-implant mucositis involves professional cleaning and improved hygiene practices, while peri-implantitis requires early intervention through mechanical debridement, surgical treatments, and supportive maintenance. The consensus also highlights technical complications, recommending careful implant positioning, material selection, and prosthesis design to prevent issues like implant fractures and screw loosening. Regular diagnostic monitoring and timely adjustments are critical for long-term success. The authors stress the need for further research, including randomized controlled trials to compare treatment protocols and evaluate patient-reported outcomes. The consensus underscores the importance of prevention and individualized management strategies, offering a comprehensive framework for improving clinical outcomes in implant dentistry [63]

There is a significant emphasis on delivering a well-fitting prosthesis, especially in edentulous implant reconstruction patients, to eradicate prosthetic maladaptation and enhance overall patient satisfaction. [48] It is, therefore, essential to understand and study any potential complications that may arise in these complex implant reconstructions. To address this issue, studies to gather more comprehensive data on implant complications are necessary to track the performance of implants over an extended period, document any adverse events or

complications that occur, and analyze the data to better understand their prevalence and potential risk factors. By expanding the scope of research to include more information on implant complications, we can gain a complete understanding of their occurrence, probable causes, and possible interventions that may be required. This knowledge will be valuable in improving implant reconstructions' long-term performance, reducing complication rates, and enhancing patient outcomes in the future. All this information can also help modify the current maintenance and recall protocol for these complex treatment modalities.

The article "Peri-implant health" by Araujo and Lindhe (2018) explores the clinical and histological characteristics of peri-implant tissues in health and their significance in identifying implant-related diseases. The authors describe peri-implant tissues as divided into soft and hard tissue compartments. The soft tissue, known as the peri-implant mucosa, comprises connective tissue and epithelium, forming a seal around the implant to protect underlying bone. This mucosa averages 3-4 mm in height, with an epithelium length of about 2 mm. The hard tissue compartment primarily involves direct contact between the implant and mineralized bone, providing stability.

The article emphasizes that deviations from these healthy characteristics can help clinicians diagnose conditions like peri-implant mucositis and peri-implantitis. The authors discuss the process of healing after implant placement, where the mucosa forms a protective seal involving a combination of connective and epithelial tissue adhesion. The paper also highlights the importance of maintaining peri-implant health through proper care and monitoring to prevent disease progression.[19]

The article by Roccuzzo et al. (2010) presents the ten-year outcomes of a prospective cohort study evaluating the survival and success of dental implants in periodontally compromised patients (PCPs) compared to periodontally healthy patients (PHPs). The study included 112 partially edentulous patients divided into three groups: PHP, moderate PCP, and severe PCP. All patients underwent periodontal therapy and implant placement, followed by individualized supportive periodontal therapy (SPT).

The findings revealed implant survival rates of 96.6% in PHPs, 92.8% in moderate PCPs, and 90% in severe PCPs, indicating lower survival rates in PCPs, particularly those with severe periodontitis. Bone loss after ten years was minimal in PHPs (0.75 mm) but significantly higher in moderate PCPs (1.14 mm) and severe PCPs (0.98 mm). Sites with ≥3 mm bone loss were notably more frequent in PCPs than in PHPs, highlighting the impact of periodontal health on long-term implant outcomes.

The study also emphasized the critical role of adherence to SPT. In severe PCPs, implant failure was observed in 57% of patients who did not adhere to SPT, compared to only 10% in those who followed the recommended maintenance regimen. Minor prosthetic complications, such as ceramic cusp fractures, were reported but not statistically analyzed.[64]

Additionally, Heitz-Mayfield et al. (2014) provided consensus statements and clinical recommendations for preventing and managing biological and technical complications associated with dental implants. Their findings underscore the importance of preventive measures and effective management strategies to improve implant success rates and mitigate complications. Together, these studies highlight the necessity of rigorous periodontal maintenance and careful patient management to ensure the long-term success of dental implants.[63]

Diagnosis and Management: Regular monitoring of peri-implant tissues includes assessing plaque levels, probing depths, and radiographic bone levels.
Peri-implant mucositis should be treated with professional cleaning and oral hygiene reinforcement, avoiding systemic antibiotics.
Peri-implantitis requires early intervention, including debridement and, in severe cases, surgical therapy to manage inflammation and prevent bone loss.

Management of Technical Complications: Emphasis on using properly designed and manufactured components to reduce risks such as implant fracture and prosthetic screw loosening.
Veneering material fractures can be minimized by ensuring adequate support from the framework and maintaining proper prosthesis design.

Early and late implant failures and unfavorable reactions in the peri-implant hard and soft tissues are examples of biological complications. Appropriate clinical and radiographic diagnostic techniques are required to detect such problems.3
thorough clinical and radiographic evaluation is necessary. Implant loss varies from location and timing; it should be categorized into 'early' or 'late' implant failure based on the timing of implant removal or lack of osseointegration.[65, 66]

Reporting on biological complications on entire arch monolithic zirconia prostheses is still considerably limited. Most clinical studies evaluate the outcome, complication, and treatments for single or short span fixed implant prostheses. It is important to interpret these statistics considering the individual patient's oral health condition, maintenance, and other factors that could influence the success or failure of the implants. Regular dental check-ups and proper oral hygiene practices are vital for long-term implant success.

Despite the biological complications, patients' quality of life changes and overall satisfaction would affect the choice of treatment options among clinicians and patients. A study by Beresford et al. [67] in 2018 evaluated 12 edentulous patients restored with a two-implant overdenture compared to a three-implant–supported fixed prosthesis in the mandible. Both therapeutic approaches yielded substantial and comparable enhancements in patient satisfaction and oral health-related quality of life when contrasted with a conventional complete mandibular

removable dental prosthesis. Nevertheless, the fixed dental prostheses demonstrated superior stability, retention, and masticatory convenience, significantly influencing patient preference in most cases.[68]

To assess patient satisfaction with IFCDPs as a treatment modality for complete edentulism or draw any conclusions on the best treatment option, it is essential to reassess how we evaluate and compare various implant prosthetic options. [69] In the literature, different methods are employed to conclude, including comparing bite forces, stability or retention, and chewing efficiency. Furthermore, the expertise of clinicians in various implant treatment modalities may impact their suggestions, driven by their familiarity with distinct implant prosthesis types or configurations. Nonetheless, the question of whether researchers or clinicians are more aptly qualified than prosthetic wearers themselves to assess these alternatives remains to be definitively ascertained. Ultimately, what matters most is the satisfaction of the patients themselves. Their feedback and level of satisfaction should be critical factors in determining the effectiveness of a treatment option. [70]

In clinical research regarding patient-reported outcome measures (PROMs), two main items are commonly evaluated: the impact of the prosthesis on "Quality of Life" and patient satisfaction. To measure the impact on "Quality of Life," the Oral Health Impact Profile (OHIP) is the most frequently used instrument. This questionnaire covers seven domains: functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap. [71] Conversely, "satisfaction" is often not described accurately in most studies, but it generally assesses functional, social, and overall satisfaction. The methods used to evaluate PROMs can vary significantly across studies, leading to heterogeneity in the field. Additionally, there is diversity in the measurement tools for PROMs, with some instruments needing proper validation. As a result, the type of scale and calculated scores can vary greatly. Unfortunately, the utilization of PROMs in clinical research is not standardized, which can lead to assumptions that may be misleading. Given the potential of PROMs to provide accurate outcomes, there is a clear need to establish standardized tools for their measurement. [72] This would help ensure more reliable and consistent results when evaluating the impact of different studies.

Regarding patient satisfaction, there is a recurring observation that IFCDPs are preferred over implant overdentures (IODs), although this preference does not often reach statistical significance [73-78]. One study by de Souza et al. [74] focused on mandibular rehabilitation using the Brånemark protocol or implant overdentures. The researchers concluded that considering the patients' preferences when selecting the type of prosthesis is crucial for treatment success. Both the IOD and IFP groups reported high levels of satisfaction, with over 87% overall satisfaction. There were no significant differences between the two groups regarding phonetic function, chewing ability, pain, improvement in self-confidence, and self-esteem. However, the reasons for choosing the specific prosthesis type differed between the two

groups. IOD patients selected treatment due to cost considerations, while dissatisfaction with a previous prosthesis was the most common reason in the IFP group. It appears that a patient's prior experience with a prosthesis can significantly influence their decision for removable or fixed implant prostheses, particularly among elderly patients.

Another study conducted by Oh et al. [77] compared patient satisfaction and oral health-related quality of life (OHRQoL) in fully edentulous patients treated with IFCDPs, IOD, or complete dentures (CD), considering both maxillary and mandibular cases. The results showed no significant difference in patient satisfaction and OHRQoL between the IFCDPs and IOD groups, but both groups demonstrated more significant improvement than the CD group. Specifically, the IFCDP group exhibited significant improvements in OHRQoL dimensions such as functional limitation, physical pain, psychological discomfort, and psychological disability. In the IOD group, functional limitation significantly improved compared to the CD group. It is worth noting that there were no significant differences between the IFCDP and IOD groups across all dimensions of OHIP-14 (Oral Health Impact Profile-14).

The findings of Brennan et al. [79] differed from those mentioned above. They assessed patient satisfaction and oral health-related quality of life (OHRQoL) before and after treatment with implant overdentures (IODs) or implant-fixed prostheses (IFCDPs). The study found that patients in the IFCDP group showed lower satisfaction with cost and experienced more difficulty with oral hygiene. In contrast, the IOD group reported significantly decreased overall satisfaction and lower satisfaction with chewing capacity and aesthetics. Another study by Martin-Ares et al. [75] also reported decreased satisfaction with oral hygiene when using IFCDPs. According to Brennan et al. [79], the IFCDP group demonstrated significantly lower levels of psychological discomfort and psychological disability than the IOD group.
Since complications may impact treatment outcomes, success rates, and patients' experiences, clinicians must recognize the associated risks and etiology duly. By doing so, they can proactively mitigate the occurrence of clinical complications and also furnish patients with pertinent evidence-based information.

Oral hygiene recommendation around implants and prosthesis
Maintaining optimal oral hygiene around implant-supported fixed complete dental prostheses (IFCDPs) is essential to prevent complications such as peri-implant mucositis, peri-implantitis, and implant failure. Proper care helps ensure the longevity of both the implants and prostheses, while also preserving the health of surrounding tissues.
Here are key oral hygiene recommendations:
1. Brushing, The use of soft-Bristled Toothbrush to clean the implant-supported prosthesis. Hard bristles may damage the implant surface or irritate the surrounding tissues.

Electric Toothbrush: An electric toothbrush with a rotating or oscillating head can be more effective in plaque removal, especially around the implant-abutment interface and in areas that are difficult to reach.

Brushing technique should be gently in a circular motion around the implant and prosthesis, paying particular attention to the margins where the implant meets the gum. It is recommended to brush twice daily for at least two minutes to remove plaque buildup.

2. Interdental Brushes: Use small interdental brushes (Proxabrush or similar) to clean the spaces between the implants and prostheses. These brushes are more effective than traditional floss in removing plaque and debris, especially around implants where there is often limited space.

Dental Floss: If the spaces allow, unwaxed dental floss can be used to gently clean between the implants. However, it's essential to be cautious to avoid damaging the gum tissue or implant surface.

Soft-Picks: For patients with sensitive gums or tight spaces, soft rubber-tipped picks may be used to clean between the implants and adjacent teeth.

3. Irrigation and Antiseptic Rinse: Using a water flosser or oral irrigator (such as Waterpik) can help remove debris and plaque from hard-to-reach areas, particularly around the implant neck and under the prosthesis. It can also help reduce inflammation in the peri-implant tissues.

Antiseptic Mouthwash: Rinsing with an alcohol-free, antimicrobial mouthwash containing chlorhexidine or essential oils (e.g., thymol, eucalyptol) can help reduce the bacterial load and prevent infection around the implant site. It is especially useful in the presence of inflammation or at-risk patients.

4. Regular Professional Cleaning: Regular dental check-ups every 3–6 months are necessary for professional cleaning of the implants and the surrounding tissues. The dental hygienist will use specialized tools, such as ultrasonic scalers and air polishing devices, to clean the implant surface without damaging it.[53]

Routine radiographs will help monitor for bone loss around the implant, ensuring any signs of peri-implantitis are detected early.

5. Avoiding Tobacco and Excessive Alcohol

Smoking can negatively impact implant success by increasing the risk of peri-implantitis, reducing blood flow to the gums, and impairing healing. It is essential to avoid smoking or significantly reduce tobacco use to maintain implant health.

Excessive alcohol consumption can also contribute to oral health problems, including increased plaque buildup and dry mouth, which may compromise implant success.[52, 53]

6. Special Considerations for Prosthesis Care like Cleaning Under the Prosthesis: For IFCDPs, it's important to ensure that debris does not accumulate under the prosthesis, as this can lead to inflammation and infection. Patients may be advised to use a special cleaning tool, like a flosser or interdental brush, designed to clean beneath the prosthesis without dislodging it.

Removable Prosthesis Maintenance: If the prosthesis is removable for cleaning, it should be carefully removed, cleaned with a non-abrasive paste or solution, and then securely replaced to avoid loosening or misalignment.

7. Custom Cleaning Tools

Interdental Brushes and Floss with Tapered Ends: Some patients may need specialized cleaning tools for implants with smaller spaces or tight contacts. Interdental brushes with tapered or angled tips can reach hard-to-clean areas, ensuring plaque is thoroughly removed.

Anti-Bacterial Agents for Implant Surfaces: Regular use of antimicrobial agents can help control bacteria around the implant surface and reduce the risk of inflammation or infection.[80]

II. Research Aim

The primary aim of the present study was to assess the implant survival and biological complications observed with monolithic zirconia implant-supported fixed complete dental prostheses (IFCDPs) in completely edentulous patients after a clinical follow-up period of at least one year.

The secondary aim was to evaluate the patient feedback through a questionnaire to evaluate the functional, physical, and psychological outcomes after treatment.

Significance

Due to the various factors that must be considered, treatment decisions for full-mouth implant fixed prostheses can vary among clinicians. In this study, we aimed to evaluate the biological complications and patient feedback in monolithic zirconia implant-supported fixed complete-arch dental prostheses after at least a one-year follow-up period. The results of this study will enhance clinicians' understanding of the potential biological complications and provide the basis for improved future treatment planning for monolithic zirconia implant-supported fixed complete-arch dental prostheses.

III. Materials and methods

This study was an observational single-center retrospective clinical cohort study performed in the Division of Postgraduate Prosthodontics at Tufts University School of Dental Medicine (TUSDM).

The present retrospective study used a convenience sample of subjects that underwent treatment with zirconia IFCDPs at TUSDM. All eligible patients identified with an axiUm dental chart record review were asked to participate in the study.

1. Subject selection: Inclusion criteria

o Patients rehabilitated at the Postgraduate Prosthodontic clinic of TUSDM.
o Age of the patient > 18 years old when they received treatment.
o Dental implants with rough surfaces.
o Completely edentulous patients who had been rehabilitated with monolithic or modified monolithic zirconia IFCDPs at one or more edentulous jaws.
o Definite prosthesis under functional loading for at least one year.
o Dental records include sex, age, implant placement date, and prosthesis delivery date.

2. Exclusion criteria

o Patients treated at different practice locations.
o Age of the patient < 18 years old when they received treatment.
o Dental implants with smooth (machined) surface for less than one year.
o Patients who wished to refrain from signing the informed consent form.
o Pregnant females were excluded due to dental X-rays, as is the standard of care at TUSDM. Female subjects were asked if they were pregnant when contacted about participation. If they were pregnant, they were invited to participate after the pregnancy.

2. Data collection/Study procedures:

Visit 1:

The subject was instructed to read the informed consent form (ICF). The subject was given ample time to have any questions answered. If a subject decided to participate, he or she was instructed to sign the ICF. A copy of the ICF was given to the subject. The subject was asked to complete demographic information and medical history. Eligibility criteria were evaluated.
A complete set of intraoral photographs was taken. After prosthesis removal, it consisted of intraoral views in maximum intercuspation (frontal and lateral) and intraoral views of maxillary and mandibular arches (frontal, buccal, palatal, and occlusal). The photographs were used to identify biological (mucosal recession) and technical complications (chipping, wear).

All of the following evaluations are done routinely at a recall appointment but were also done at this visit as part of the research study. An oral exam, including evaluation of the oral cavity, soft and hard tissues, was completed following standard of care procedures. A periodontal probe assessed the Pocket Depths and Bleeding on Probing around the implants.
In detail, the following periodontal parameters were assessed:
1. Presence or absence of peri-implant suppuration and/or fistula.
2. Probing Depth (PD) was measured with a periodontal probe to the nearest millimeter at six sites around the implants.
In detail, the following clinical parameters were recorded:

1. Presence/absence of an IFCDP,
2. Jaw and location,
3. Number of replaced teeth and number of abutments,
4. Presence/absence of nightguard,
5. Presence/absence of bruxism,

Digital periapical radiographs of each implant were obtained from the subject except if they already existed within a period of 6 months prior and without any change in clinical status since the last visit. Radiographs were taken following standard-of-care methods (including wearing a lead apron to reduce unnecessary exposure).

The subject was given a short questionnaire after completion of the comprehensive examination. The IFCDPs were examined for any complications or failures during the clinical examination. If subjects were in need of treatment due to complications, then they were informed about it. The patients were given the choice of whether they preferred to be treated at TUSDM for the complications, at normal clinic fees, if they were still TUSDM patients attending the recall, or they preferred to be referred back to their dentists if they were not TUSDM patients anymore. All evaluations followed the standard of care guidelines.

After Visit:
A record review of the subject's AxiUm dental chart was done after the study visits to record complications or failures prior to the single research visit.
Additionally, the radiographic assessment was completed. In detail, areas of peri-implant bone loss >2mm were identified, and results were confirmed with periodontal clinical examination findings.
Patient, implant prosthesis and opposing dentition general information can be seen in Table 1.

Evaluation of biological complications

• Minor complications were considered those for which only chairside treatment was needed, including soft tissue recession; inflammation under the fixed prosthesis; peri-implant mucositis; and hypertrophy/hyperplasia of soft tissue.
• Major complications were those that needed additional treatment and costs, such as peri-implantitis, advanced bone loss, and late implant failure.

The definition and data collection type of all minor and major biological complications were as follows:

Peri-implantitis: Diagnosis of peri-implantitis is given in the presence of peri-implant mucositis with progressive bone loss. Implant probing depth of more than 5mm, with bleeding and/or suppuration on probing, and radiographic bone loss of more than 1.8mm are the criteria for diagnosing peri-implantitis.

Peri-implant mucositis: Inflammation of the peri-implant mucosa without continuing marginal bone loss. Bleeding on probing surrounds the abutment area without suppuration. Soft tissue recession: The clinical attachment loss (CAL) was recorded at six sites of mesiobuccal, mid-buccal, distobuccal, mesiolingual, mid-lingual, and distolingual aspects and measured in millimeters for six sites.

Advanced bone loss: Bone loss exceeding 2mm after one year of functional loading, examined through periapical films.

Hypertrophy/hyperplasia of soft tissue: Soft tissue overgrowth around the prosthesis during visual clinical exam.

Inflammation under prosthesis: Redness after prosthesis removal; the clinical examination was performed by two calibrated examiners and confirmed verified by 1 of the committee members.

Late implant failure: An event leading to the loss of the implant or the need to remove the implant.

Sample size calculations:

Sample size calculations were conducted using nQuery Advisor 9.1.1.0 (Statistical Solutions Ltd., Cork, Ireland). As the primary aim of the study was to estimate the implant success rate, as opposed to hypothesis testing, the calculations were conducted to evaluate the anticipated precision of the two-sided 95% confidence interval for the implant success rate (rather than the assessment of statistical power, which is appropriate for hypothesis testing). Based on the findings of Papaspyridakos et al.,[29] the anticipated implant success rate was 100%; for the calculations, a value of 99% was used in order to ensure a valid precision. The calculations accounted for the presence of multiple prostheses for some subjects using the methodology of Killip et al.[81] Based on the recommendation of Killip et al., the intracluster correlation coefficient was assumed to be $\rho = 0.01$ or $\rho = 0.02$, and a separate power calculation was

performed for each value of ρ. Both calculations demonstrated that the obtained sample size of 44 subjects and 61 prostheses was adequate to obtain a two-sided 95% confidence interval with an anticipated half-width of 4%, which was considered adequate precision. Furthermore, sensitivity analyses were undertaken in which the value of ρ was conservatively assumed to be 0.10 or 0.20. Even under these conservative assumptions, the obtained sample size was still sufficient to obtain a two-sided 95% confidence interval with an anticipated half-width of less than 5%, which was considered adequate precision.

IV. Statistical analysis

Descriptive statistics (means, medians, standard deviations, and interquartile ranges for continuous variables; counts and percentages for categorical variables) were calculated. For implant failure, the Kaplan-Meier curve and 95% confidence interval were computed. Associations were assessed using generalized estimating equations (GEE) to account for the presence of correlated data. Specifically, GEE binary logistic regression was used for binary outcomes. For count outcomes, both GEE Poisson regression and GEE negative binomial regression were run, and the results with a lower QIC statistic were reported. In all cases, Poisson regression had a lower QIC statistic than negative binomial regression. P-values less than 0.05 were considered statistically significant. SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and Stata 17 (StataCorp LLC, College Station, TX, USA) were used in the analysis.

V. Results

The present study aimed to evaluate the demographic and clinical characteristics of patients receiving monolithic zirconia IFCDPs, with a particular focus on implant loading times and the biological complication.

The study involved 44 patients, consisting of 20 females (45.5%) and 24 males (54.5%), and 61 arches, consisting of 32 maxillary arches, comprising 52.46%, and 29 mandibular arches, accounting for 47.54% of the total. were predominantly White (95.1%) and Non-Hispanic (88.5%). The patients demonstrated a low prevalence of smoking (13.1%) and diabetes (6.6%). Medical history reviews indicated no reports of cancer or jaw radiation, and only a minimal use of bisphosphonates (3.3%).

Regarding oral habits, the majority of the patients (83.6%) reported not using night guards, while 19.7% had a history of bruxism. The patients exhibited a balanced distribution of prosthetic placement, with 54.1% in the maxilla and 45.9% in the mandible. The study also noted a conservative approach towards implant loading, with 91.8% not immediately loaded, 80.3% not early loaded, and 57.4% opting for delayed loading.

In total, the follow-up duration for the implants with mean on 28.67 and SD of 18.33. The implants used were primarily of the moderate rough surface type from manufacturers like Nobel

Biocare and Straumann. The majority of prostheses did not feature ridge lap designs (88.5%), and all were restored at the abutment level.

Biological Complications

The study observed several types of biological complications, though major complications were infrequent. Implant loss and advanced bone loss (>2mm) were recorded in 0.8% and 3.4% of cases, respectively. Minor complications were more prevalent, with issues such as soft tissue hyperplasia and recession affecting a small percentage of the cohort. The most common issues encountered were related to implant maintenance, including the management of plaque and the stability of the implants over time.

There was a total of 61 biological complication events, affecting 25 arches of IFCDPs. The most frequent biological complication found in this study was inflammation under the prosthesis (25 arches, 40.3%), where gingival redness on the alveolar ridge with food impaction was observed following prosthesis removal intraorally. The second most common complication noted was peri-implant mucositis, assessed by probing the six sites of each abutment. Bleeding on probing was observed in 18 abutments, representing an incidence rate of 29.0% among the implants in this study.

Regarding other minor complications, soft tissue hyperplasia was observed in 6 arches (9.7%), and soft tissue recession was found at 2 sites, representing an incidence rate of 3.2%. As for major complications, advanced bone loss was observed in 9 implants (14.5%), while implant loss was reported in 1 implant (1.6%).

Minor complications were more frequently encountered than major complications. The mean (SD) number of minor complications was 1.4 (1.2), while the mean (SD) numbers of major complications and total complications were 0.3 (0.6) and 1.7 (1.3), respectively.

Summary of results for inflammation under a prosthesis:
The analyses indicate that no significant associations were found between the examined variables and inflammation under a prosthesis. Individuals with without ridge LAP exhibited lower odds of inflammation (OR = 0.14), while those with a maxillary jaw type showed slightly higher odds (OR = 1.24), both lacking statistical significance (p-values of 0.383 and 0.339, respectively). Non-smokers demonstrated lower odds of inflammation compared to smokers (OR = 0.441), and those who identified as females had lower odds compared to those that identified as males (OR = 0.71), yet both results were also not statistically significant (p-values of 0.398 and 0.574, respectively). Table 4.

Summary of results for hypertrophy/hyperplasia of soft tissue:
Results of risk factors for hypertrophy/hyperplasia of soft tissue indicate that individuals without Ridge LAP were less likely to experience this condition, with an odds ratio of 0.21 and a p-value of 0.07, suggesting a potential trend but not reaching statistical significance. Those with maxillary jaws showed a similar trend with an odds ratio of 0.91, but this difference was not significant either. Non-smokers demonstrated lower odds of hypertrophy/hyperplasia (OR = 0.71), while individuals identifying as females were slightly more likely to be affected compared to those identifying as males (OR = 1.31), though neither of these findings reached statistical significance. Table 5.

Summary of findings for Peri-implant Mucositis:
The results for risk factors for peri-implant mucositis reveal that individuals without Ridge LAP were less likely to experience this condition, with an odds ratio of 0.28 and a p-value of 0.051, suggesting a trend toward significance. While there were no significant differences in the prevalence of mucositis between maxillary and mandibular jaw types (OR = 0.73, p = 0.213), smokers showed higher odds (OR = 2.01, p = 0.55), although this was not statistically significant. Additionally, those that identified as females exhibited lower odds of mucositis compared to those that identified as males (OR = 0.72, p = 0.62), but this also lacked statistical significance. Table 6.

Summary of results for advanced bone loss:
Risk of advanced bone loss across various factors show that individuals without Ridge LAP and those with Ridge LAP showed comparable likelihoods of advanced bone loss, reflected by an odds ratio of 0.93. Similarly, maxillary and mandibular jaw types exhibited negligible differences in advanced bone loss (OR = 1.07). Additionally, there was no significant difference in advanced bone loss between genders, with an odds ratio of 1.18 for males. Non-smokers exhibited lower odds of advanced bone loss compared to smokers (OR = 0.24), but the p-value of 0.17 shows this finding was not statistically significant. Table 7.

Summary of results for Major complications:
Results from major complications analysis reveal that individuals without Ridge LAP had a slightly lower likelihood of experiencing complications compared to those with Ridge LAP, with an odds ratio of 0.76. Smokers showed a slightly higher likelihood of major complications than non-smokers, with an odds ratio of 1.35. Lastly, individuals identifying as females exhibited a lower likelihood of complications compared to those identifying as males, with an odds ratio of 0.16. However, none of the results reached statistical significance. Table 8.

Summary of results of Minor Complications:
Individuals with Ridge LAP had an increased likelihood of experiencing minor complications, with an odds ratio of 1.7. Meanwhile, the odds of experiencing minor complications were similar between individuals with maxillary and mandibular jaws, with an odds ratio of 1.31. Smokers showed a reduced likelihood of minor complications compared to non-smokers, with an odds ratio of 0.63. Additionally, individuals identifying as females had a lower likelihood of experiencing minor complications compared to males, with an odds ratio of 0.48. However, none of these findings reached statistical significance. Table 9.

Summary of findings for total complications:
Results for total complications show that individuals with Ridge LAP exhibited a similar likelihood of complications compared to those without Ridge LAP, with an odds ratio of 0.999. Similarly, no significant differences were seen between individuals with maxillary and mandibular jaws, as indicated by an odds ratio of 1. Smoking status also revealed comparable likelihoods of complications, with an odds ratio of 0.84 for smokers compared to non-smokers. In contrast, individuals identifying as female demonstrated a notably lower likelihood of total complications, with an odds ratio of 0.25 relative to males, and P value of 0.05, the results were significant. Table 10.

For all results key findings

The analysis of various risk factors for inflammation, hypertrophy/hyperplasia of soft tissue, and complications revealed several trends, although many findings did not reach statistical significance.

For inflammation under a prosthesis, individuals without Ridge LAP were significantly less likely to experience inflammation compared to those with Ridge LAP (OR = 0.14). Individuals with maxillary jaws had a slightly elevated likelihood of inflammation (OR = 1.24), but this was not statistically significant. Non-smokers tended to have lower odds of inflammation than smokers (OR = 0.44), and females showed lower odds compared to males (OR = 0.71). Despite these observed trends, none of the p-values indicated statistically significant associations.

In the context of hypertrophy/hyperplasia of soft tissue, individuals without Ridge LAP were similarly less likely to experience this condition (OR = 0.21), indicating a potential trend. The odds were comparable for jaw types, with neither maxillary nor mandibular jaws showing significant differences. Non-smokers were also less likely to experience hypertrophy/hyperplasia, while females displayed slightly higher odds compared to males. Again, none of these associations reached statistical significance.

Regarding peri-implant mucositis, individuals without Ridge LAP had lower odds of this condition (OR = 0.28), approaching statistical significance. Maxillary jaw type had no significant impact, while smokers displayed higher odds than non-smokers but remained statistically insignificant. Females had a lower likelihood of mucositis compared to males, though not significant.

The analysis revealed that individuals without Ridge LAP showed a similar likelihood of advanced bone loss as those with Ridge LAP, with an odds ratio of 0.93, indicating no significant association. Additionally, individuals with maxillary and mandibular jaws displayed comparable odds of advanced bone loss, with an odds ratio of 1.07. Non-smokers exhibited lower odds of advanced bone loss (OR = 0.24) compared to smokers, although this finding was not statistically significant. The results for gender indicated that both females and males had similar odds of advanced bone loss (OR = 1.18).

In terms of major complications, individuals without Ridge LAP were slightly less likely to experience complications compared to those with Ridge LAP, with an odds ratio of 0.76; however, this finding was not statistically significant. For jaw type, maxillary and mandibular jaws demonstrated no significant differences in complication rates, with the odds ratio at 1. Individuals who smoked showed a slightly higher likelihood of suffering from complications compared to non-smokers (OR = 1.35), but this result was also not statistically significant. Gender differences were notable, as females exhibited a substantially lower likelihood of experiencing major complications compared to males, with an odds ratio of 0.16, and P value of 0.11indicating a non significant finding.

The patient satisfaction questionnaire evaluated various aspects of post-treatment experiences, including pronunciation, sense of taste, discomfort, self-perception, and overall functionality. Results showed that 68.2% of patients never experienced trouble pronouncing words with their prosthesis, although 21.4% occasionally faced this issue. The majority (93.2%) reported no changes in their sense of taste, with only 6.8% noticing occasional declines. Half of the respondents (50.0%) reported no painful aching, while 28.6% experienced it occasionally. Similarly, 64.3% did not report discomfort while eating, though 14.3% occasionally experienced this issue, and 7.1% felt it fairly often. Regarding self-consciousness, 71.4% were never bothered by their appearance post-treatment, but 14.3% reported feeling self-conscious fairly often or very often.

Most participants rarely felt tense (77.3%) or dissatisfied with their diet (85.7%). Interruptions during meals were uncommon, with 79.5% never facing this issue, though a small percentage (7.1%) occasionally experienced interruptions. Relaxation difficulties were rare, with 86.4%

reporting no issues. Embarrassment was also minimal, as 79.5% never felt embarrassed by their prosthesis, and 13.6% experienced occasional embarrassment. Social interactions remained positive, with 90.9% never feeling irritable with others. Similarly, 90.9% did not find their prosthesis affecting job performance, and 93.2% reported good overall functionality. However, 14.3% occasionally felt their life was less satisfying post-treatment, and 4.5% faced occasional functional challenges.

VI. Discussion

Comprehensive dental rehabilitation for edentulous patients underwent profound improvements. The pioneering studies reported remarkably successful outcomes in implant placement and prosthesis application, leading to a paradigm shift in the field.[11, 67, 79].

The purpose of this cohort study was to retrospectively evaluate the biological complications, survival rates, and the patients' reported outcomes with IFCDPs after at least one year of delivery.

Inflammation under prosthesis was this study's most common minor biological complication (25 arches, 40.3%), In 2012 Papaspyridakos et al.[35] analyzed 120 metal resin IFCDPs and found that tissue inflammation under the prosthesis occurred in 11 arches. The estimated annual incidence rate was 1.1%, and the 5 and 10-year complication rates were 5.6% and 11.3%. Soft tissue inflammation under the prostheses is highly associated with the presence of biofilm. Metal resin was proven more prone to plaque accumulation and calculus deposition compared to zirconia base due to the surface smoothness. Soft-tissue inflammation observed under both materials appears to be highly associated with areas of plaque accumulation The prosthetic base design on the recruited patient would also have an impact on the accessibility of homecare cleaning for the patients.[70] It was suggested that the design of the IFCDPs base be convex to flat, sightly touching the soft tissue without excessive pressure for better oral hygiene maintenances and less biofilm formation. However, there are no specific terms for the IFCDPs' prosthetic base design like there were for FPD bridges. The recommendation is based on the clinician's findings during the follow-up visit, the healthy soft tissue response and correlated prosthetic base design.[60]

Three arches were found to have soft tissue hyperplasia upon prosthesis removal. Was observed in 6 arches (9.7%), and soft tissue recessionwas found at 2 sites, representing an incidence rate of 3.2%., similar to Papaspyridakos et al.'s findings in 2012; 13.0% and 26.0% after 5 and 10 years, respectively. [12] One arch in this study was found to have extreme hypertrophy (figure 2), causing pain and swelling, requiring further periodontal surgery to improve the patient's cleaning ability and better prosthetic maintenance. This uncommon and remarkable scenario, seldom encountered in prior studies, involves medication-induced gingival hyperplasia resulting from the patient's daily usage of contraceptive pills.

Soft tissue recession around the implant shows the greyish color of titanium implant's collar or threads. It is accompanied by a lack of keratinized tissue surrounding the abutment, marginal bone loss and the implant often causes problems with cleaning and poor esthetic. A 10-year implant-based mucosal recession rate of 77% was reported by Papaspyridakos et al. 2018[14], compared to 1.6% in the mean five years follow-up found in our study. Lacking the baseline comparison in the present study, the amount of annual recession cannot be quantified. [40]
This comprehensive assessment helps delineate the various factors influencing the success and longevity of monolithic zirconia IFCDPs, highlighting both the effectiveness and areas for improvement in clinical practices.

In a systematic review assessing 534 implants on metal-resin or metal-ceramic IFCDPs,[35] there was an estimated annual overall complication rate of 2.1%. In the present study bleeding on probing was observed in 18 abutments, representing an incidence rate of 29.0%. This finding is highly related to the tithe patient's oral hygiene compliance, the prosthetic design, and the abutment selection.
Radiographic examination found marginal bone loss >2mm observed in 9 implants (14.5% compared to the previous studies by Papaspyridakos et al. [14] in 2018, the average bone loss around implants under the functional load of 5 years was 0.6 mm (0.5–0.7 mm), and more than five years was 0.9 mm (0.7–1.1 mm).
Due to the different designs of the implants, the patient's oral habits, and lacking the standardized baseline radiographic comparison in the present study, the amount of annual bone loss cannot be quantified.
Two implants failed during prosthesis removal, which served as the terminal mandibular site. It was a 6mm tissue-level implant without any previous symptoms or indications of failure. The overall implant survival rate was 97.7% after a mean observation period of 60.5 months in the present study. The cumulative implant survival rates were 97.7% on both maxillary and mandible IFCDPs in the previously reported studies.[58, 82] Overall, the mid-term implant survival rate (5-10 years) was high. Still, late implant loss is considered a significant complication. Malo et al. [83] reported that nearly 70% of late implant failure patients refuse further surgical intervention, leaving the problem unsolved. This will contribute to an increasing possibility of consequent prosthetic failure.

In this observational study, patient satisfaction rates were high. More than 80% reported no issue with function, physiological or psychological problems. Similar to previous articles' findings, implant-supported fixed prostheses showed improvements in various parameters of quality of life.
Despite the rise in patients needing complete arch prostheses, fixed or removable, there needs to be more widespread enforcement regarding recall regimens for patients with implant-borne

restorations. Evidence suggests that lifelong professional recall regimens are necessary to ensure proper maintenance for patients with implant-borne fixed or removable restorations, considering their individual needs. Specific oral and topical agents and hygiene aids can significantly enhance these restorations' professional and at-home maintenance [53]. It is important to note that different prosthetic materials and designs require unique mechanical and biological maintenance. Consequently, personalized clinical practice guidelines are essential for the recall and maintenance of patients with implant-borne dental restorations. [53]
In a recent retrospective study, Bardis et al. [70] assessed various biological risk factors among complications in fixed implant prosthetic therapy. They showed that in terms of implant success, the absence of biological and technical complications was observed in only 66.3% of cases. The prevalence of biological complications stood at 13.5%, while technical complications were evident in 28.7% of cases. Certain variables, such as poor oral hygiene and bruxism, were associated with a higher risk of periimplantitis. Univariate analysis indicated that poor oral hygiene increased the risk of peri-implantitis by 5.8 times, whereas bruxism increased it by 5.9 times; overall, these findings emphasize the importance of maintaining good oral hygiene and addressing any issues with bruxism to reduce the risk of implant complications. No associations were feasible in this study due to the small sample size.

A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses [84]. This systematic review compares the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit implant-supported fixed dental prostheses (FDPs). Analyzing 19 studies (16 on metal-ceramic FDPs and 3 on zirconia-ceramic FDPs), it evaluated 932 metal-ceramic and 175 zirconia-ceramic prostheses over a follow-up period of at least three years. The findings revealed that metal-ceramic FDPs exhibited a significantly higher 5-year survival rate (98.7%) compared to zirconia-ceramic FDPs (93.0%). Additionally, metal-ceramic FDPs had fewer complications, including lower rates of ceramic chipping and no reported framework fractures. In contrast, zirconia-ceramic FDPs showed a higher incidence of framework fractures and chipping (50% vs. 11.6% for metal-ceramic FDPs). The primary failure causes for zirconia-ceramic FDPs were catastrophic failures and ceramic fractures, whereas metal-ceramic FDPs demonstrated better long-term performance. The study concluded that conventionally veneered zirconia is not recommended as the first choice for implant-supported FDPs due to higher complication risks. Although monolithic zirconia presents potential, its long-term outcomes need further evaluation, reaffirming metal-ceramic FDPs as the gold standard for these restorations.

Limitations

The first limitation of this study is the single-center retrospective design, which introduced sampling bias due to its reliance on data obtained from files and records recorded by diverse clinicians. Another limitation is the small sample size; we could only rely on a convenience

sample and patient compliance for recall, which constrained the study. Finally, the missing standardized radiographic evaluation and lack of baseline photos of prostheses at delivery made it hard to accurately compare the soft tissue and bone level changes.

VII. Conclusion

Considering the frequent occurrence of biological complications, it is imperative for the clinician to be aware of the incidence rates to implement personalized maintenance and recall protocols for their patients. For certain patients, periodic prosthesis removal may become necessary as part of a meticulous maintenance protocol for prostheses. This protocol entails a thorough assessment of any alterations in the medical history and a comprehensive evaluation of peri-implant soft tissues to detect any signs of inflammation. The frequency of prosthesis removal in each unique case can be determined by the condition of the peri-implant tissues and the cleanliness of the prosthesis intaglio upon removal. Patient satisfaction with IFCDP is high regarding the aspects of function, physiological and psychological components.

APPENDICES

Appendix A:

Table 1.

Category	Description	Number of Patients/Arches	Percentage
Gender	Female	20	44.26%
	Male	24	55.74%
Race	White	58	95.08%
	Asian	2	3.28%
	Black	1	1.64%
Ethnicity	Non-Hispanic	54	88.52%
	Hispanic	6	9.84%
	African American	1	1.64%
Smoking History	No	53	86.89%
	Yes	8	13.11%
Diabetes	No	57	93.44%
	Yes	4	6.56%
Cancer History	No	60	98.36%
	Yes	1	1.64%
Bisphosphonates Use	No	59	96.72%
	Yes	2	3.28%
Night Guard Use	No	54	88.52%
	Yes	7	11.48%
Bruxism History	No	53	86.89%
	Yes	8	13.11%
Arch Distribution	Maxilla	33	54.10%
	Mandible	28	45.90%
Ridge Lap Design	No	54	88.52%
	Yes	7	11.48%
Immediate Loading Time	Yes	9	14.75%
Early Loading Time	Yes	1	1.64%
Delayed Loading Time	Yes	51	83.61%

Table 2. Plaque index, total number of major and minor complications, Mean, Median, Standard Deviation (SD) and Interquartile Range (IQR) values.

Variable	Mean	Std. Deviation	Median	25th	75th
Plaque Index (%)	39.28	24.6	35.0	17.5	52.0
Total number complications	0.67	1.17	0.0	0.0	1.0
Minor number Complications	0.49	0.98	0.0	0.0	1.0
Major number Complications	0.13	0.34	0.0	0.0	0.0
Number with Implant Loss	0.02	0.13	0.0	0.0	0.0
Number with Advanced Bone Loss (>2mm)	0.23	0.82	0.0	0.0	0.0
Number with Soft Tissue Recession	0.03	0.18	0.0	0.0	0.0
Number of Implants	5.82	0.56	6.0	6.0	6.0
Age (years)	66.98	12.1	70.0	62.0	75.0
Months with Prosthesis	28.67	18.33	20.0	13.0	37.0
Months with Implants in Mouth	53.37	28.74	50.0	39.0	63.0

Table 3. Biological complications

Complication	Response	N	%
Inflammation under prosthesis	Yes	25	40.3
Inflammation under prosthesis	No	36	58.1
Soft tissue recession	1	2	3.2
Soft tissue recession	0	59	95.2
Hypertrophy/hyperplasia of soft tissue	Yes	6	9.7
Hypertrophy/hyperplasia of soft tissue	No	55	88.7
Peri-implant mucositis	Yes	18	29
Peri-implant mucositis	No	43	69.4
Advanced bone loss	1	9	14.5
Advanced bone loss	0	52	83.9
Implant loss	1	1	1.6
Implant loss	0	60	96.8

Table 4. Risk factors for inflammation under a prosthesis

Ridge LAP	No Inflammation (%)	Yes Inflammation (%)	Odds Ratio (95% CI)	P
No	35 (64.8%)	19 (35.2%)	0.14 (0.002 - 11.19)	0.383
Yes	1 (14.3%)	6 (85.7%)		
Jaw Type	No Inflammation (%)	Yes Inflammation (%)	Odds Ratio (95% CI)	P-value
Maxillary	19 (59.4%)	13 (40.6%)	1.24 (0.796 - 1.94)	0.339
Mandibular	17 (58.6%)	12 (41.4%)		
Smoking Status	No Inflammation (%)	Yes Inflammation (%)	Odds Ratio (95% CI)	P-value
Non-Smoker	32 (60.4%)	21 (39.6%)	0.441 (0.066 - 2.94)	0.398
Smoker	4 (50.0%)	4 (50.0%)		
Gender	No Inflammation (%)	Yes Inflammation (%)	Odds Ratio (95% CI)	P-value
Identify as female	17 (63.0%)	10 (37.0%)	0.71 (0.216 - 2.34)	0.574
Identify as male	19 (55.9%)	15 (44.1%)		

Table 5. Risk factors for Hypertrophy/Hyperplasia of Soft Tissue

Ridge LAP	Hypertrophy/Hyperplasia of Soft Tissue		OR (95% CI)	P
	No	Yes		
No	50 (92.6%)	4 (7.4%)	0.205 (0.037–1.14)	0.07
Yes	5 (71.4%)	2 (28.6%)		
Jaw Type	Hypertrophy/Hyperplasia of Soft Tissue		OR (95% CI)	P
	No	Yes		
Maxillary	29 (90.6%)	3 (9.4%)	0.914 (0.183–4.57)	0.91
Mandibular	26 (89.7%)	3 (10.3%)		
Smoking status	Hypertrophy/Hyperplasia of Soft Tissue		OR (95% CI)	P
	No	Yes		
No	48 (90.63%)	5 (9.38%)	0.71 (0.07–7.75)	0.78
Yes	7 (87.50%)	1 (12.50%		
Gender	Hypertrophy/Hyperplasia of Soft Tissue		OR (95% CI)	P
	No	Yes		
Identify as female	24 (88.9%)	3 (11.1%)	1.31 (0.24–7.25)	0.76
Identify as male	31 (91.2%)	3 (8.8%)		

Table 6. Risk factors for Peri-implant Mucositis

Ridge LAP	Peri-implant Mucositis		OR (95% CI)	P
	No	Yes		
No	42 (77.8%)	12 (22.2%)	0.283 (0.08 - 1.00)	0.051
Yes	1 (14.3%)	6 (85.7%)		
Jaw Type	Peri-implant Mucositis		OR (95% CI)	P
	No	Yes		
Maxilla	24 (75.0%)	8 (25.0%)	0.727 (0.440 - 1.20)	0.213
Mandible	19 (65.5%)	10 (34.5%)		
Smoking	Peri-implant Mucositis		OR (95% CI)	P
	No	Yes		
No	36 (67.9%)	17 (32.1%)	2.01 (0.21 - 19.90)	0.55
Yes	7 (87.5%)	1 (12.5%)		
Gender	Peri-implant Mucositis		OR (95% CI)	P
	No	Yes		
Identify as female	21 (77.8%)	6 (22.2%)	0.72 (0.20 - 2.57)	0.62
Identify as male	22 (64.7%)	12 (35.3%)		

Table 7. Risk factors for Advanced Bone Loss

Ridge Lap	Advanced bone loss		OR (95% CI)	P
	No	Yes		
No	46 (85.2%)	8 (14.8%)	0.934 (0.172 - 5.07)	0.9372
Yes	6 (85.7%)	1 (14.3%)		
Jaw type	Advanced bone loss		OR (95% CI)	P
	No	Yes		
Maxilla	27 (84.40%)	5 (15.60%)	1.07 (0.60 - 1.93)	0.8
Mandible	25 (86.20%)	4 (13.80%)		
Smoking	Advanced bone loss		OR (95% CI)	P
	No	Yes		
No	47 (88.70%)	6 (11.30%)	0.24 (0.03 - 1.81)	0.17
Yes	5 (62.50%)	3 (37.50%)		
Gender	Advanced Bone Loss		OR (95% CI)	P
	No	Yes		
Identify as female	23 (85.20%)	4 (14.80%)	1.18 (0.25 - 5.51)	0.83
Identify as male	29 (85.30%)	5 (14.70%)		

Table 8. Risk factors for Major Complications

Ridge Lap	Major Complications		OR (95% CI)	P
	No	Yes		
No	47 (87.00%)	7 (13.00%)	0.76 (0.12 - 4.79)	0.77
Yes	6 (85.70%)	1 (14.30%)		
Jaw (Mx=1/Md=2)	Major Complications		OR (95% CI)	P
	no	yes		
Maxillary	28 (87.5%)	4 (12.5%)	0.76 (0.298-1.94)	0.56
Mandible	25 (86.2%)	4 (13.8%)		
Smoking	Major Complications		OR (95% CI)	P
	No	Yes		
No	46 (86.80%)	7 (13.20%)	1.35 (0.16 - 11.20)	0.78
Yes	7 (87.50%)	1 (12.50%)		
Gender	Major Complications		OR (95% CI)	P
	No	Yes		
Identify as female	26 (96.3%)	1 (3.7%)	0.16 (0.02 - 1.49)	0.11
Identify as male	27 (79.4%)	7 (20.6%)		

Table 9. Risk factors for Minor Complications

Ridge Lap	Minor Complications		OR (95% CI)	P
	No	Yes		
No	42 (77.8%)	12 (22.2%)	1.7 (0.85 - 4.20)	0.24
Yes	0 (0.0%)	7 (100.0%)		
Jaw type	Minor Complications		OR (95% CI)	P
	No	Yes		
Maxilla	21 (65.6%)	11 (34.4%)	1.31 (0.78 - 2.22)	0.3
Mandible	21 (72.4%)	8 (27.6%)		
Smoking	Minor Complications		OR (95% CI)	P
	No	Yes		
No	37 (69.8%)	16 (30.2%)	0.63 (0.09 - 4.26)	0.64
Yes	5 (62.5%)	3 (37.5%)		
Gender	Minor Complications		OR (95% CI)	P
	No	Yes		
Identify as female	21 (77.8%)	6 (22.2%)	0.48 (0.13 - 1.78)	0.27
Identify as male	21 (61.8%)	13 (38.2%)		

Table 10. Risk factors for Total Complications

Ridge Lap	Total Complications		OR (95% CI)	P
	No	Yes		
No	38 (70.4%)	16 (29.6%)	0.999 (0.997 - 1.00)	0.26
Yes	1 (14.3%)	6 (85.7%)		
Jaw type	Total Complications		OR (95% CI)	P
	No	Yes		
Maxilla	20 (62.5%)	12 (37.5%)	1 (0.999 - 1.00)	0.72
Mandible	19 (65.5%)	10 (34.5%)		
Smoking	Total Complications		OR (95% CI)	P
	No	Yes		
No	34 (64.2%)	19 (35.8%	0.84 (0.13 - 5.64)	0.86
Yes	5 (62.5%)	3 (37.5%)		
Gender	Total Complications		OR (95% CI)	P
	No	Yes		
Identify as female	22 (81.5%)	5 (18.5%)	0.25 (0.06 - 0.97)	0.05
Identify as male	22 (81.5%)	5 (18.5%)		

Table 11. OHIP-14 Questionnaire results: N (%)

	Never (%)	Hardly Ever (%)	Occasionally (%)	Fairly Often (%)	Very Often (%)
Trouble Pronouncing	30 (68.2)	6 (13.6)	6 (13.6)	2 (4.5)	0 (0.0)
Sense of Taste Gets Worse	41 (93.2)	0 (0.0)	3 (6.8)	0 (0.0)	0 (0.0)
Painful Aching	33 (75.0)	5 (11.4)	6 (13.6)	0 (0.0)	0 (0.0)
Uncomfortable Eating	31 (70.5)	6 (13.6)	5 (11.4)	2 (4.5)	0 (0.0)
Self-conscious	35 (79.5)	2 (4.5)	2 (4.5)	3 (6.8)	2 (4.5)
Feeling Tense	34 (77.3)	3 (6.8)	4 (9.1)	1 (2.3)	2 (4.5)
Unsatisfactory Diet	35 (79.5)	3 (6.8)	5 (11.4)	1 (2.3)	0 (0.0)
Interruption During Meal	35 (79.5)	5 (11.4)	3 (6.8)	0 (0.0)	1 (2.3)
Difficult to Relax	38 (86.4)	3 (6.8)	2 (4.5)	1 (2.3)	0 (0.0)
Embarrassment	35 (79.5)	1 (2.3)	6 (13.6)	0 (0.0)	2 (4.5)
Being Irritable with Others	40 (90.9)	4 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)
Difficulty Doing Usual Jobs	40 (90.9)	4 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)
Life Less Satisfying	36 (81.8)	2 (4.5)	4 (9.1)	1 (2.3)	1 (2.3)
Totally Unable to Function	41 (93.2)	1 (2.3)	2 (4.5)	0 (0.0)	0 (0.0)

Appendix B: Figures

APPENDICES

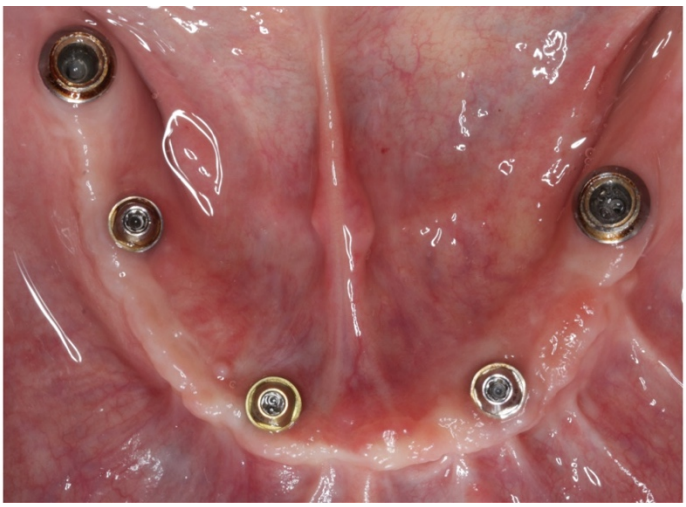


Figure 1. Healthy soft tissue

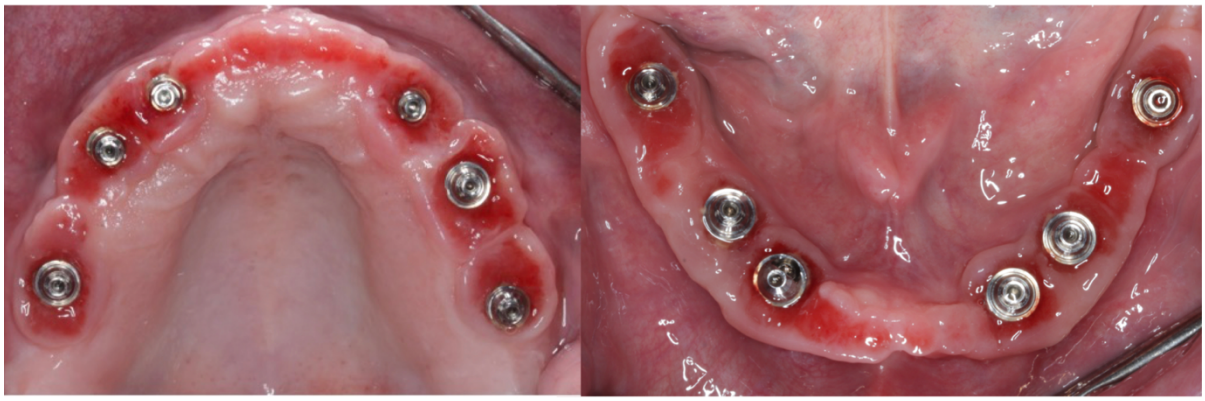


Figure 2. Inflammation under prosthesis

34

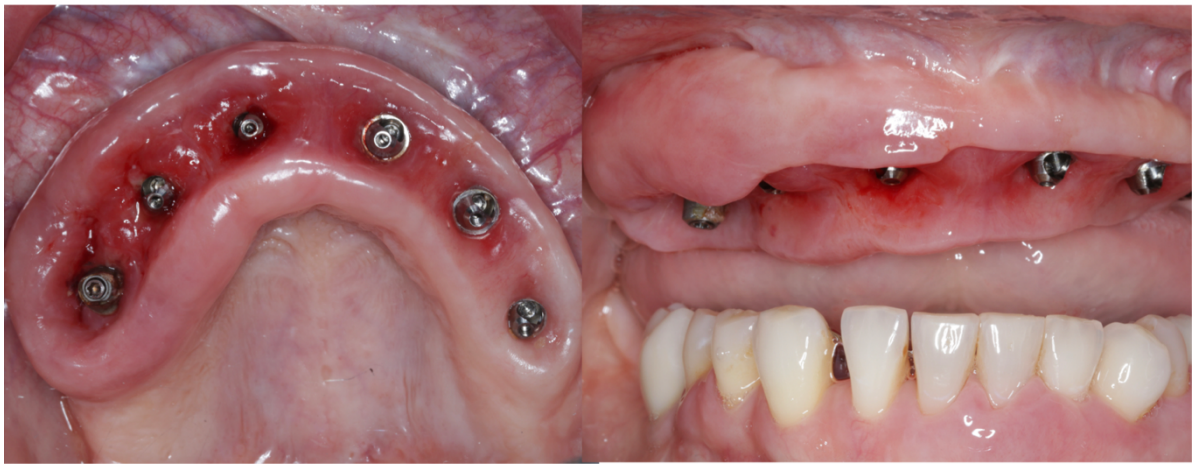


Figure 3. Hypertrophy/Hyperplasia of soft tissue

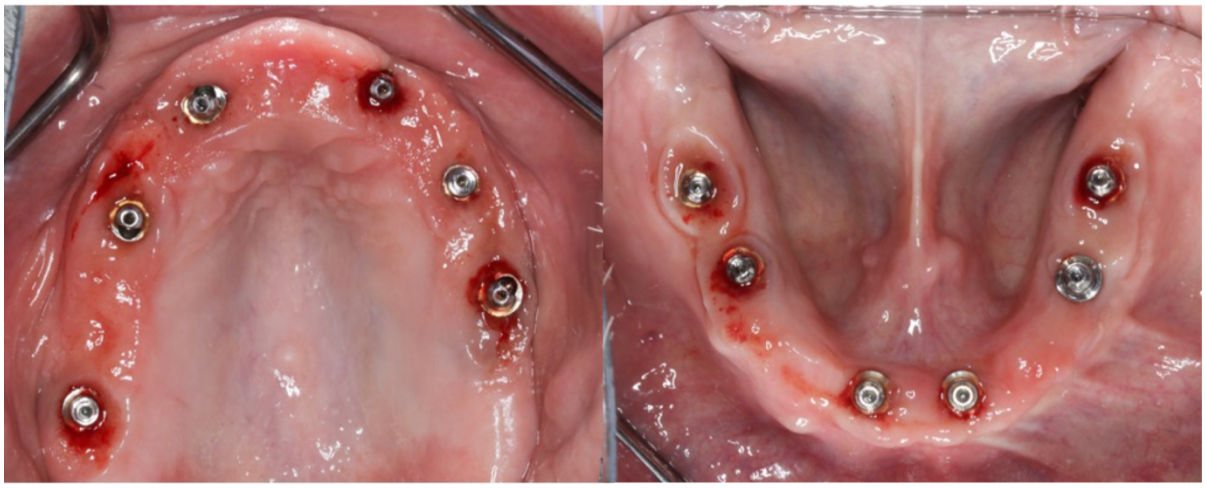


Figure 4. Peri-implant mucositis.

35

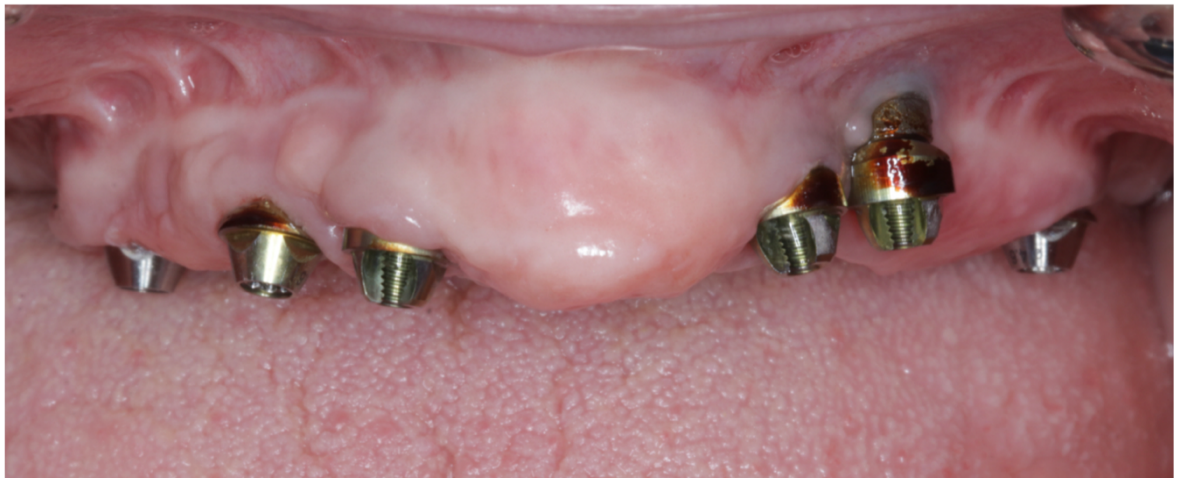
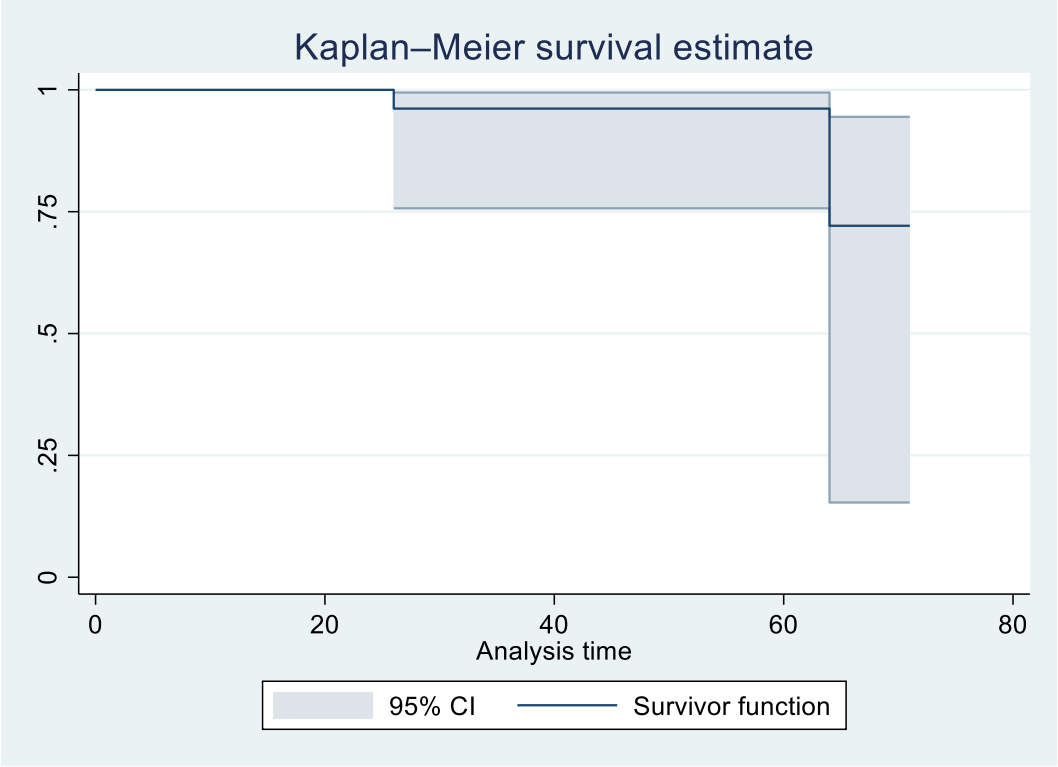


Figure 5. Soft tissue recession

Kaplan-Meier curve with a two-sided 95% confidence interval:



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