Tufts UNIVERSITY | School of Dental Medicine

Survival Rates, Technical Complications and Dimensions of Monolithic Zirconia Fixed Complete Arch Dental Prostheses

by

Ahmad Malluh

December 2024

TABLE OF CONTENTS

THESIS COMMITTEE

Thesis Advisor

Panos Papaspyridakos, DDS, MS, PhD

Associate Professor

Department Prosthodontics

Tufts University School of Dental Medicine

Boston MA

DSc Student Co-Investigator:

Ahmad Malluh

Department Prosthodontics

Doctorate of Science in Dentistry Program

Committee Members

Konstantinos Vazouras DDS, DMD

Assistant Professor

Program Director of Advanced Education in Prosthodontics

Department Prosthodontics

Tufts University School of Dental Medicine

Boston MA

Matthew Finkelman, PhD

Associate Professor

Department of Public Health and Community Service

Tufts University School of Dental Medicine

Boston MA

Yukio Kudara, C.D.T.

Assistant Professor

Department Prosthodontics

Tufts University School of Dental Medicine

Boston MA

ACKNOWLEDGMENTS

I extend my heartfelt gratitude to my thesis advisor, Dr. Panos Papaspyridakos, for his invaluable guidance, expertise, and unwavering support throughout this journey.

To the esteemed members of my thesis committee, Dr. Konstantinos Vazouras, Dr. Matthew Finkelman, and Mr. Yukio Kudara, your insights and feedback greatly enriched this work.

To my family, your unconditional love, encouragement, and patience have been my anchor throughout this journey. To my parents, who instilled in me the value of hard work and perseverance; to my wife, whose unwavering support and understanding have been my greatest strength; to my brothers, who have stood by me with encouragement and pride; to my sister, whose belief in me has always inspired me; and to my niece, whose laughter and joy bring light to my life—I am forever grateful.

I am privileged to have been guided and supported by such remarkable individuals. Your contributions have been instrumental in the success of my doctoral thesis.

ABSRACT:

OBJECTIVE:
The primary objective of this study was to assess the survival and complication rates of monolithic zirconia implant-supported fixed full dental prostheses (IFCDPs) in completely edentulous patients following a minimum 1-year clinical follow-up. Additionally, the study sought to evaluate associations between risk indicators, structural dimensions, and quality-of-life outcomes.

MATERIALS AND METHODS:
This observational, single-center retrospective cohort study included a convenience sample of 44 participants who received 61 zirconia IFCDPs at Tufts University School of Dental Medicine (TUSDM). Data on demographics, clinical variables, technical complications, and prosthesis dimensions were collected. Descriptive statistics were calculated, and associations between independent variables and complications were analyzed using generalized estimating equations (GEE). Statistical analyses were performed using SPSS v.28 (IBM Corp., Armonk, NY, USA) and SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS:
The study included 44 participants (45.5% female, 54.5% male; mean age 67.07 (SD=12.1) years) with a mean prosthesis use duration of 28.67 (SD=18.32) months. The majority (72.7%) did not use a nightguard, and 25% reported bruxism. Opposing dentition included natural teeth (13.1%), implant-supported prostheses (50.8%), removable prostheses (14.8%), a combination of teeth and implants (19.7%), and implant overdentures (1.6%). Of the 61 prostheses, 52.5% were maxillary, and 47.5% were mandibular. Minor technical complications included Ti-base decementation (13%), chipping (12%), loss of access hole material (13%), and wear of prosthetic screws (11.5%). Major complications were infrequent, with fracture of screws (2%) and fracture of frameworks (3%). The overall prosthesis survival rate was 93.44%, with a mean total complication rate of 0.8 (SD=1.15)events per prosthesis. Structural analysis identified reduced dimensions at critical cross-sections as potential contributors to fractures.

CONCLUSION:
This study demonstrated a 93.44% survival rate for monolithic zirconia IFCDPs over an average follow-up period of 28.67 months. While the prostheses showed high reliability, minor technical complications were relatively common, highlighting the need for routine maintenance. The findings underscore the importance of prosthesis design and risk factor consideration in treatment planning. Larger, multicenter studies with longer follow-up periods are recommended to validate these findings and provide greater insights into the long-term performance of zirconia prostheses.

I) Background and rationale

The global rise in population, combined with a growing percentage of elderly individuals, has led to an increased demand for treatments addressing edentulism. Although the overall prevalence of edentulism is on the decline, the need for such care continues to grow due to the expanding population of adults aged 55 and older. [1]

Complete loss of teeth in one or both dental arches significantly impacts anatomy, functionality, aesthetics, and psychological well-being, resulting in a considerable decline in patients' comfort and quality of life.[2] Traditionally, the only available treatment was a removable full denture that relied on physical, chemical, and biomechanical retention. However, this approach often fell short of ensuring patient satisfaction, particularly for those with low alveolar ridges or minimal retention capability. In contrast, implant-supported fixed prostheses, supported by strong clinical and scientific evidence, now offer a reliable solution for addressing total edentulism with enhanced patient satisfaction.[3]

Historically, complete-arch fixed implant-supported prostheses were crafted using noble alloy frameworks veneered with acrylic resin or denture teeth.[4] About 30 years ago, Brånemark introduced the mandibular screw-retained metal-resin implant fixed complete dental prosthesis (MRIFCDP), initially referred to as a hybrid or fixed bone-anchored prosthesis.[5 6] These restorations involved attaching denture teeth to a metal framework using acrylic resin and were supported by six implants placed between the mental foramina. Today, similar prosthetic designs are used with four to six implants.[7] Among the available options, metal-acrylic hybrid prostheses remain one of the most thoroughly researched solutions for restoring edentulous arches with permanent implants.

The continued preference for MRIFCDPs is attributed to their long-standing record of clinical success, cost-effectiveness, ease of repair, and familiarity among clinicians.[8] Compared to traditional dentures or implant-retained overdentures, MRIFCDPs have been shown to improve patients' oral health-related quality of life. Fixed prostheses provide superior functionality, aesthetics, and emotional satisfaction over removable alternatives, leading to enhanced patient outcomes.[9] Research by Barootchi et al. revealed that metal-acrylic prostheses demonstrated a survival rate of 83.0% ± 11.1% at 5 years, which declined to

51.7% ± 12.1% at 8 years and further at 10 years.[10] Over 10 years, 51% of the hybrid prostheses experienced fractures in the denture teeth. [10] Other studies have highlighted veneer fractures as a common complication for metal-acrylic IFCDPs, with nearly 70% of such prostheses showing some veneer damage after 15 years.[11] Similarly, Purcell et al. reported that, over an average recall period of 7.9 years, 28 out of 46 MRIFCDPs exhibited denture teeth fractures, indicating a high incidence of such failures.[12]

Numerous clinical investigations and systematic reviews consistently report high rates of fracture and wear in acrylic resin components, necessitating frequent repairs, replacements, and ongoing maintenance. This ongoing care often translates to increased financial costs and reduced satisfaction for both patients and practitioners.[8]

According to Mackert et al. (2022), MRIFCDPs demonstrate relatively low survival rates, with only 54% remaining functional after 5 years and 32% after 10 years. Common complications include acrylic resin fractures, screw loosening or breakage, denture teeth wear, framework fractures, and poor gingival aesthetics.[13] In the 1990s, English proposed that cantilever lengths could extend up to 1.5 times the anteroposterior implant spread [14] However, using prostheses with posterior cantilevers can increase the risk of distal extension failure when interacting with natural teeth or other implant-supported prostheses.[13, 15] The most frequent reason for MRIFCDP replacement is catastrophic acrylic resin fractures around the metal bar, followed by denture teeth wear.[13] Papaspyridakos et al. reported that abutment screw loosening was the most common technical issue in MRIFCDPs, while screw fractures occurred due to excessive occlusal loading caused by parafunctional habits.[16] Chipping or fracturing of veneering material remains the most reported technical complication for MRIFCDPs, followed by the loss of screw-access filling material.[16]

As highlighted in previous studies, hybrid prostheses are prone to numerous complications. Recent advancements in dental technology have introduced titanium and other materials for frameworks, alongside dental ceramics or composites for veneering.[4] Metal-composite resin or metal-ceramic frameworks are now conventional alternatives to metal-acrylic resin fixed complete dentures.[8]

In a retrospective study, Chochlidakis et al. evaluated the survival rates and technical complications of complete fixed prostheses over a 5-year follow-up period.[17] Out of 48 prostheses, 10 were metal-ceramic, and 38 were metal-acrylic resin. In the metal-acrylic resin group, the most common minor complication was the loss of access hole material at a rate of 5.26% annually, while the metal-ceramic group reported minor wear of the prosthetic material at 9.37% annually. Both groups experienced major wear of the prosthetic material, the most frequent major complication, with rates of 5.49% and 7.45% for the metal-acrylic and metal-ceramic groups, respectively) No significant differences were observed between the groups in terms of patient satisfaction.[17] After 3.5 years of observation, IFCDPs showed a cumulative survival rate of 88%. The study also found a significant correlation between the absence of an occlusal device and higher rates of minor chipping, access hole material loss, and framework fractures.[17]

Papaspyridakos et al. conducted a study focusing on double full-arch implant prostheses, which included 38 IFCDPs—28 metal-ceramic (MC) and 10 metal-resin (MR) prostheses.[18] Over an average follow-up period of 5.1 years (ranging from 1 to 12 years), the survival rate was 92.1%. The most frequently reported significant technical complication was material breakage, with an estimated dental-unit rate of 8.0% over 5 years. The cumulative complication-free rate for prostheses after 5 years was 57.1%. The study emphasized that not using a nightguard and having porcelain-based materials increased the risk of chipping or fracturing, particularly in bruxism patients.[18] A separate study by Gonzalez et al., with a five-year follow-up period, evaluated 80 full-arch implant-supported metal-porcelain prostheses among 65 patients.[2] This study identified mechanical and technical complications related to implant diameter, abutment connections, and retention systems. The most common complications were the loss of screw access hole fillings and porcelain fractures, although the survival rate for metal-ceramic prostheses remained high.[2]

In a 2019 retrospective cohort study, Papaspyridakos et al. assessed the biological and technical complications of MC IFCDPs over an average follow-up period of 5 years.[19] The study found that the proportion of prostheses “free from minor technical complications” dropped from 58.0% at 5 years to 10.1% at 10 years. Conversely, the cumulative rate of prostheses free from major complications was 90.4%

after 5 years but declined to 49.1% after 10 years. Among the minor technical issues, porcelain wear occurred at an annual rate of 8.0%, while porcelain fractures, a major complication, were observed at a rate of 0.8% per year at the dental-unit level.[19] Both hybrid and metal-ceramic prostheses are expensive, complex to fabricate, and challenging to repair, which limits their widespread application.[8] Additional studies are necessary to assess the financial burden associated with maintaining complete-arch implant-supported prosthetics.[19]

Advances in prosthodontics have been driven by the introduction of innovative dental materials and technologies. Various prosthetic options, including crowns, fixed dental prostheses, and removable prostheses, are now manufactured using diverse materials and laboratory techniques. With the growing adoption of osseointegrated implants, fixed prostheses are increasingly used even for completely edentulous cases. [20] Recent trends emphasize aesthetics and patient-centered outcomes,[3] with monolithic zirconia becoming a popular clinical option.[21]

The use of zirconia (ZrO_2) as a high-performance ceramic began with a study by Garvie et al. in 1975.[22] Zirconia, a crystalline dioxide of zirconium, exhibits mechanical properties similar to metals while closely resembling natural teeth in color.[23, 24] It exists in three crystal phases: monoclinic, tetragonal, and cubic.[25, 26] These phases change with temperature—monoclinic up to 1170°C, tetragonal up to 2370°C, and cubic above that.[23, 26] Stabilizing the tetragonal phase is possible by incorporating oxides like Y_2O_3, MgO, CeO, or CaO.[26] However, mechanical processes like grinding and sandblasting can cause a phase transformation from tetragonal to monoclinic,[26, 27] accompanied by a 3–4% volume expansion. This transformation generates compressive stresses that halt crack propagation.[26, 28]

Y-TZP ceramics possess transformation toughening properties, enhancing fracture strength and toughness compared to other dental ceramics.[23] In 1969, zirconium oxide was first proposed for medical use, particularly in orthopedics, as a material for hip head replacements. Early studies involving its use in monkey femurs demonstrated no adverse reactions.[24] During the 1990s, zirconia entered dentistry and became widely adopted through computer-aided design and manufacturing (CAD/CAM) technology.[25, 29]

Clinical studies have confirmed zirconia's reliability as a framework material for implant-supported crowns and fixed dental prostheses, thanks to its proven success in tooth-supported restorations.[29-31]

Zirconia stands out in dentistry due to its low thermal conductivity, resistance to corrosion, and excellent radiopacity.[24] Y-TZP (yttria-stabilized tetragonal zirconia polycrystals) is particularly valued for its high flexural strength (900–1200 MPa) and fracture toughness (9–10 MPa), which result from a transformation toughening mechanism.[23, 29, 32]

This versatility has made Y-TZP a key material for various dental applications, including root canal posts, all-ceramic posterior tooth frameworks, implant-supported crowns and prostheses, custom-made bars, implant abutments, and dental implants.[29]

A study by Mundha et al. compared enamel wear against zirconia crowns, metal-ceramic crowns, and natural enamel. After a year, zirconia crowns caused significantly less enamel wear in the premolar and molar regions than metal-ceramic crowns.[33] Additionally, bacterial adhesion, which is critical for preventing marginal infiltrations and periodontal complications, was notably lower on zirconia compared to other materials. Scarano et al. reported a bacterial coverage rate of 12.1% on zirconia versus 19.3% on titanium.[34] Similarly, an in vivo study by Rimondini et al. showed that Y-TZP surfaces accumulated fewer pathogenic bacteria than titanium.[24]

Zirconia has gained popularity in modern dentistry due to its excellent biocompatibility, low bacterial adhesion, high flexural strength, toughness resulting from transformation toughening, and aesthetic qualities.[21] Additionally, Digital workflows and computer-aided design and manufacturing (CAD/CAM) zirconia restorations have transformed the management of restorative challenges in complete-arch implant prostheses. Ceramic-veneered zirconia frameworks are widely recommended for such restorations.[35, 36] These advanced workflows leverage precise techniques to streamline the design and manufacturing processes, ensuring improved outcomes for both patients and clinicians.[37-40] The progression of CAD/CAM technology has played a significant role in advancing the field of prosthodontics. Coupled with the need to address issues such as chipping of layering ceramics and the demand for reliable aesthetic results, CAD/CAM innovations have driven the increased adoption of monolithic (full-contour) zirconia

as a material of choice for IFCDPs, reflecting the growing emphasis on durability, precision, and predictability in prosthetic designs.[8, 39-46]

However, further research is necessary to address the common issue of ceramic veneer chipping and the less frequent problem of framework failure.[35, 47] A retrospective study by Papaspyridakos and Lal was the first to evaluate the 2- to 4-year clinical outcomes and technical complications of screw-retained porcelain-fused-to-zirconia IFCDPs for edentulous patients. The study concluded that while this prosthetic option is viable for 2–4 years, it presents challenges, with the most frequent technical issue being porcelain chipping or fracture, occurring at a rate of 31.25%.[21] Monolithic zirconia prostheses, designed as an alternative to complete-arch fixed prostheses, offer a uniform structure that eliminates the presence of different interfaces, thereby reducing the risk of fractures or chips.[35] These features have established zirconia-based restorations as a potential substitute for traditional porcelain-fused-to-metal (PFM) restorations.[21]

Two recent systematic reviews highlight zirconia's potential as a promising alternative for implant prostheses. Abdulmajeed et al. noted that while clinical evidence on the long-term outcomes of zirconia CAFIPs is limited, monolithic zirconia shows high short-term success rates.[35] However, there remains a lack of clinical data regarding survival rates and technical complications for monolithic zirconia implant-supported prostheses.[35] Bidra's systematic review compared clinical outcomes of monolithic zirconia and zirconia veneered with porcelain, finding minimal short-term failure risks. Monolithic zirconia with gingival stains or partial porcelain veneering shows promising outcomes, but further long-term studies are required. [48]

Furthermore, a study by Barootchi et al. compared zirconia full-arch implant-supported prostheses to metal-acrylic hybrids, finding zirconia prostheses to be initially more expensive but associated with fewer complications and improved survival rates.[10] Pozi et al. retrospectively evaluated zirconia-based full-arch prostheses over 12 years, concluding that they are a reliable treatment for partial and complete edentulism. The study reported a cumulative prosthetic survival rate of 98.2% and a prosthetic success rate of 91.9%, despite six cases of chipping fractures.[49]

Thompson et al. conducted a cohort study in 2023 examining the 1-year and 5-year survival rates of zirconia IFCDPs. Among 67 treated arches, 9 failures were recorded, including framework fractures, patient-related concerns, implant loss, and veneering porcelain fractures. The survival rates were 88.8% after 1 year and 72.5% after 5 years.[43] Four failures were observed in cases where both arches used zirconia IFCDPs [43]

The dimensions of prostheses, including their height and thickness, play a critical role in influencing their fracture resistance.[42-46] Ensuring appropriate dimensional properties during the design phase is essential to maintaining the structural integrity of the prosthesis under functional loads.[42-46] However, the long-term evidence on optimal thickness dimensions for zirconia IFCDPs remains limited, as most studies have been constrained by short follow-up periods.[8, 40, 44, 46, 50, 51]

Although research has explored the effects of cantilever thickness and length, the scientific understanding of zirconia thickness—particularly at connector sites and around implant access holes—remains inconsistent.[45, 50, 52, 53] This inconsistency arises from variations in the types of zirconia studied and the predominance of expert opinions rather than comprehensive clinical data.[45, 50, 52, 53]

The literature suggests that zirconia prostheses should have a minimum thickness of 11–12 mm, as determined by subjective linear measurements using Boley gauges.[39] The study reported an impressive cumulative prosthesis survival rate of 99.4%, with only one instance of prosthesis fracture, attributed to the proximity of adjacent implants.[39] However, the study faced limitations, particularly in the evaluation of prosthetic space, as the assessments were based on linear rather than three-dimensional (3D) cross-sectional measurements. Another study by Papaspyridakos et al. also highlighted the significance of evaluating prosthetic dimensions three-dimensionally, recommending a comprehensive approach to designing prostheses to ensure optimal biomechanical performance and long-term success. These findings underline the necessity of moving beyond linear measurements and adopting advanced 3D evaluations for the reliable fabrication of zirconia.[54]

Consequently, a clear consensus on the optimal dimensions for zirconia IFCDPs has yet to emerge.[52, 53] In light of this uncertainty, various recommendations have been proposed to ensure the long-term success

of monolithic zirconia prostheses.[52, 53] While a few clinical studies have evaluated the impact of thickness and height, additional research is needed to develop evidence-based guidelines.[52, 53]

Moreover, critical factors such as the dimensions around implant access holes, connector sites, and the surface area in these regions must be carefully considered to minimize the risk of mechanical complications in monolithic zirconia IFCDPs.[42, 52, 53] Despite these advancements, most clinical studies on monolithic zirconia IFCDPs have not thoroughly examined the relationship between cross-sectional zirconia dimensions and the prevalence of technical complications.[10, 21, 42-44, 49, 55-58] This knowledge gap highlights the need for further investigation to optimize prosthesis designs and improve clinical outcomes.[10, 21, 42-44, 49, 55-58]

Understanding how prosthetic treatments impact patient satisfaction and quality of life is essential in guiding clinicians and patients toward informed treatment decisions. A study by Beresford et al. highlighted that both two-implant overdentures and three-implant-supported fixed prostheses in the mandible improved patient satisfaction and oral health-related quality of life compared to conventional removable prostheses. However, fixed prostheses demonstrated superior retention, stability, and chewing efficiency, making them the preferred option for many patients.[44, 59]

Evaluating patient satisfaction with implant-supported fixed complete dentures (IFCDPs) or other treatment modalities requires a systematic approach to compare the functional, social, and overall benefits of various prosthetic options.[60] Common metrics in the literature include assessments of bite forces, prosthetic retention, and chewing efficiency. However, it remains an open question whether the perspectives of researchers and clinicians are sufficient or whether patient-reported outcomes should be prioritized in defining treatment success. Ultimately, patients' experiences and satisfaction should serve as the foundation for evaluating prosthetic interventions, as they provide invaluable insight into the true impact of these treatments.[60]

In clinical research, patient-reported outcome measures (PROMs) are frequently used to assess the impact of prostheses on quality of life and satisfaction. Among these, the Oral Health Impact Profile (OHIP) is a widely recognized tool that evaluates seven dimensions, including functional limitations,

physical pain, and social disability. While satisfaction is often assessed in studies, the metrics used to evaluate it are inconsistent, with variations in the instruments and scales applied.[61, 62] The lack of standardization in PROMs underscores the need for validated, universally accepted tools to ensure consistency and reliability in assessing treatment outcomes.[62]

The literature reveals a trend favoring IFCDPs over implant overdentures (IODs) in terms of patient preference, although the differences are not always statistically significant.[63-68] For instance, de Souza et al. found that while both IFCDPs and IODs achieved high levels of satisfaction, patient preferences were shaped by prior prosthetic experiences and economic considerations. Cost was the primary factor influencing IOD selection, whereas dissatisfaction with prior removable prostheses often motivated patients to choose fixed solutions.[64]

Similar findings were reported by Oh et al., who compared patient satisfaction and oral health-related quality of life across IFCDPs, IODs, and complete dentures (CDs) for both maxillary and mandibular restorations. While IFCDPs and IODs demonstrated comparable improvements in satisfaction and quality of life, both far outperformed conventional dentures. IFCDPs, in particular, showed significant improvements in functional limitations, psychological discomfort, and psychological disability.[67]

In contrast, Brennan et al. observed distinct differences in patient satisfaction between IFCDPs and IODs. While IFCDPs were associated with improved psychological well-being, they also presented challenges, including higher dissatisfaction with cost and oral hygiene maintenance. Conversely, IODs were linked to lower satisfaction with chewing function and aesthetics but were generally easier to clean.[9, 65] These findings emphasize the importance of balancing patient preferences with practical considerations, such as hygiene and cost.

Selecting the optimal treatment protocol for edentulous patients presents surgical and prosthetic challenges. [69] Ideally, treatment plans should be based on robust long-term evidence. Comparative studies are still needed to determine the superiority of specific therapy options.[69]

Complications in implant dentistry can be categorized as biological or technical. Biological complications involve issues affecting peri-implant tissues, leading to implant function disruption.[16] In

contrast, technical complications refer to mechanical damage to implants, components, or prostheses. Although these issues may not result in implant loss, they often increase repair and maintenance demands.[16] Few studies have quantified the costs associated with IFCDPs and their maintenance, which are important factors in patient decision-making. Long-term efficacy, cost, and maintenance heavily influence treatment preferences from a socioeconomic perspective.[16]

Aim /Objective

1- to assess prosthesis survival rates and also evaluate potential risk factors associated with increased technical complication rates. (primary objective)

2- to assess technical complication rates observed with implant-supported fixed complete dental prostheses (IFCDPs) in completely edentulous patients after clinical follow-up period of at least 1 year and examining the association with risk indicators. (secondary objective)

3- to measure the height, thickness and square surface of each prosthesis in different cross-sections (connectors, abutments, pontics), and investigate their impact on IFCDPs. (secondary objective)

4- to assess patient satisfaction and quality of life parameters, further contributing to the understanding of the impact of IFCDPs on patients. (secondary objective)

II) Materials and methods:

A) Experimental Design

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).

B) Sample Size

A convenience sample of subjects that underwent treatment with zirconia IFCDPs at TUSDM was used in the present retrospective study. 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 prosthesis survival rate, as opposed to hypothesis testing, the calculations were conducted to evaluate the anticipated precision of the two-sided 95% confidence interval for the prosthesis survival rate (rather than the assessment of statistical power, which is appropriate for hypothesis testing). Based on the findings of Papaspyridakos et al.,[54] the anticipated survival rate was 98.26%. The calculations accounted for the presence of multiple prostheses for some subjects using the methodology of Killip et al.[70] 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 4.5%, 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.

C) Statistical Analysis

Descriptive statistics were calculated. Kaplan-Meier curves were computed (Figure 10). To account for the presence of correlated data, associations with binary outcomes were assessed using generalized estimating equations (GEE) binary logistic regression, while associations with outcomes expressed as counts were assessed using GEE Poisson regression or GEE negative binomial regression. The decision to use GEE Poisson regression or GEE negative binomial regression was based on the QIC statistic. In cases where the outcome variable was homogeneous for a level of the independent variable, the approach of White et al.[71] was used. P-values less than 0.05 were considered statistically significant. SAS 9.4 (SAS Institute Inc., Cary, NC, USA) was used in the analysis.

Inclusion Criteria:

- Only patients who were rehabilitated at the Postgraduate Prosthodontic Clinic of TUSDM were included.
- Age of the patient > 18 years old at time that they received treatment.
- Rough surface dental implants.
- Only completely edentulous patients that have been rehabilitated with monolithic or modified monolithic zirconia IFCDPs at one edentulous jaw at least.
- A minimum of 1 year under functional loading.

Exclusion Criteria:

- Patients who did not meet the inclusion criteria were excluded.
- Patients with less than 1 year since the insertion of the final prosthesis.
- Patients who did not wish to sign the informed consent form were excluded.
- Pregnant females were excluded due to dental x-rays, as per the standard of care at TUSDM. When contacted about participation, female subjects were asked if they were pregnant. If they were pregnant, they were invited to participate after the pregnancy.

Only completely edentulous patients who had received rough surface implants were eligible for inclusion in the study. The completely edentulous patients had already received a zirconia IFCDP. Implant surgeries followed established surgical principles, which were adhered to at TUSDM. All implant surgeries were performed either by faculty or by postgraduate residents under the supervision of faculty.

Definitions:

Prosthesis survival was defined as prosthesis remaining in situ with or without modifications during the entire observation time.[18]

Success was defined as an implant-supported FDP being free of all complications over the entire observation period.[72]

Failure was defined as restoration having been removed or failure was defined as an event leading to the loss of the prosthesis. [47] The need to renew the entire implant-supported prosthesis as well as reported “repairs”; and The explantation/loss of the implant and therefore also the loss of the implant-supported prosthesis.[73].

The California Dental Association rating system for quality was used to characterize ceramic failures as either acceptable (surface is deficient but can be polished) or unacceptable (surface is fractured and restoration must be repaired or replaced). For simplicity, the previous descriptions were replaced by the terms porcelain chipping (minor complication) and porcelain fracture (major complication).[18]

Technical complication: [16, 18, 47]

Wear of the prosthetic material

Chipping of prosthetic material

Loss of screw access filling

Loosening of a screw

Loosening of an abutment screw

Fracture of the prosthetic material

Framework fracture

Fracture of a screw

Fracture of an abutment

Fracture of an implant

Fracture of the opposing restoration,

Study Procedures (Table 1)

Visit 1 (Approximately 1-1.5 hours):

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 a medical history.

Eligibility criteria were evaluated. A full set of intraoral photographs was taken. This 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 technical complications (chipping, wear).

All of the following evaluations were routinely performed at a recall appointment; however, they were conducted 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 in US dentistry using a mouth mirror, periodontal probe, and dental explorer.

In detail, the following prosthodontics parameters were assessed:

1. Presence/absence of an IFCDP,
2. Jaw and location,
3. Number of replaced teeth and number of abutments,
4. Location of implants and number of prosthetic segments (if not 1-piece),
5. Prosthetic materials used to fabricate the prosthesis,
6. Presence of a mesial/distal cantilever extension,
7. Presence/absence of nightguard,
8. Presence/absence of bruxism,
9. Type of opposing dentition,
10. Occlusal scheme,
11. Wear of prosthetic material,
12. Fracture of prosthetic material (chipping)

Regarding occlusal scheme, the occlusion was assessed as either mutually protected occlusion with anterior guidance or with group function. Attrition or wear was estimated as absent, localized, or generalized. The opposing dentition was categorized according to the presence of naturally restored or unrestored teeth, implant-supported restorations, or a removable partial denture.

Digital periapical radiographs of each implant were obtained from the subject unless they already existed within a period of 6 months prior, with no changes in clinical status since the last visit.

Radiographs were taken following standard of care methods (including the use of a lead apron to reduce unnecessary exposure).

The subject was given a short questionnaire after completion of the comprehensive examination. During the clinical examination, the IFCDPs were also examined for any complications or failures. If subjects needed treatment due to complications, they were informed about it. Patients were given the choice to be treated at TUSDM for the complications, at normal clinic fees, if they were still TUSDM patients attending the recall, or to be referred back to their dentists if they were no longer TUSDM patients. All evaluations followed standard of care guidelines. All study team members were calibrated for all procedures to ensure each could conduct the entirety of the study visits. The subject was given a short questionnaire after the completion of the comprehensive examination.

After Visit 1:

A record review of the subject's AxiUm dental chart was conducted after the completion of the study visit to document complications or failures that had occurred prior to the single research visit. These were defined as follows: short-term if they occurred within 1–3 years, mid-term if they occurred within 3–5 years, and long-term if they occurred after 5 years since the definitive prosthesis insertion. The definitive prosthesis insertion served as the time baseline.

After the patient appointment. For each one of the evaluated definitive prostheses, the Standard Tessellation Languages (STL) files of the CAD designed prosthesis were imported in a metrology software (Geomagic Control X, v.2022.01) to perform the following digital measurements:[54]

1- The maximum height and thickness recording in mm, in the site of each connector, based to the sectional plane with the minimum sectional area (Figure 6a,1b).
2- Connector area recording in mm^2, in the site of each connector, based to the sectional plane with the minimum sectional area (Figure 6c).
3- The maximum height and thickness recording in mm, for the buccal and the lingual section of each screw access opening, based to the sectional plane with the minimum sectional area. (Figure 7a,7b).
4- Implant section areas recording in mm^2, for the buccal and the lingual section of each screw access opening, based to the sectional plane with the minimum sectional area (Figure 7c).
5- The maximum height and thickness recording in mm, in the site of each posterior space, based to the sectional plane with the minimum sectional area (Figure 8a,8b).
6- Posterior space area recording in mm^2, in the site of each posterior space, based to the sectional plane with the minimum sectional area (Figure 8c).
7- The maximum height and thickness recording in mm, in the site of each anterior space, based to the sectional plane with the minimum sectional area (Figure 9a,9b).
8- Anterior space area recording in mm^2, in the site of each anterior space, based to the sectional plane with the minimum sectional area (Figure 9c)

Subject Withdrawal/Termination Criteria

– Subjects who decided to stop participating in the study were withdrawn.

– The Principal Investigator (Dr. Panos Papaspyridakos) determined whether subjects (either withdrawn subjects or subjects completing the study) were in need of additional treatment and/or follow-up observation as a result of participation in this trial.
If complications were found, the patients were informed accordingly.
Emergency medical treatment was given to subjects if they became hurt or sick as a direct result of being in this research study. Their insurance carriers were required to pay for any such medical care. Any needed medical care was made available at the usual cost. All needed facilities, emergency treatment, and professional services were available, just as they were to the general public. The institution did not pay for treatment if a subject became ill or injured as part of this study.

If the clinician found that a patient needed dental treatment (e.g., a problem with an implant, a cleaning, etc.), they were referred to the clinic to seek care at the usual dental clinic fees, or, if they preferred, they were referred to their own private dentists if they were no longer TUSDM patients.

Assessment

- Risk

Participation was voluntary and based on an adequate understanding of the project. Participants had an absolute right to withdraw from the study at any point. The clinical examination was equivalent to a regular recall visit where clinical parameters were measured. This was a single-visit study with minimal risk to the patient.

The radiation exposure from dental x-rays for this study was variable, ranging between 1 and 10 mrem. A dose of 10 mrem was equivalent to the natural background exposure that individuals receive over a period of 10 days.

There was a risk of loss of confidentiality to the subject by participating in this study (e.g., a subject's identity could potentially be revealed). This risk was minimized by following the procedures listed under the confidentiality section.

- Benefits

There was no direct benefit to the subjects for their participation in this study.

- Alternatives

Patients could choose not to participate in the study.

Subject Safety

1) Adverse Event Reporting

Adverse Events

An adverse event was defined as any untoward or unfavorable medical occurrence in a human subject, including any abnormal physical exam or laboratory finding, symptom, or disease, temporally associated with a subject's participation in the research.

Adverse events were recorded in source documents and on case report forms. All adverse events and non-serious situations were recorded, monitored, and reported to the IRB at the time of continuing review or at the study's termination if this occurred before the study's next continuing review.

Serious Adverse Events

A serious adverse event was defined as one that resulted in death, was life-threatening, resulted in hospitalization or prolongation of existing hospitalization, resulted in a persistent or

significant disability/incapacitation, resulted in a congenital anomaly/birth defect, or jeopardized the subject's health and required medical or surgical intervention to prevent one of the other outcomes listed above.

Serious adverse events were recorded in source documents and on case report forms. Serious adverse events were reported to the IRB within 15 business days.

Unanticipated Problems

An unanticipated problem was defined as an incident, experience, or outcome that met all of the following criteria: 1) The nature, severity, or frequency was unexpected for the subject population or research activities as described in the current IRB-approved protocol, supporting documents, and the ICF(s); 2) it was related or possibly related to participation in the research; 3) it suggested that the research placed the subject or others at a greater risk of harm than was previously recognized.

Unanticipated problems were recorded in source documents and on case report forms. Unanticipated problems were reported to the IRB within 2 business days after the PI/study team became aware of the problem. An Event Reporting Form was submitted to the IRB no later than 5 business days after the PI/study team became aware of the problem.

Subject Participation

1) Screening:

   The PI (Dr. Panos Papaspyridakos) and Co-Investigators (Drs. Konstantinos Vazouras, Ahmad Malluh) conducted screening examinations to identify subjects who met the inclusion/exclusion criteria for enrollment in the study.

2) Informed Consent:

   Dr. Panos Papaspyridakos and the other co-investigators, Konstantinos Vazouras and Ahmad Malluh, introduced the study.

   Consenting took place in a private clinic bay area, and the patients were given as much time as they needed to consider participation. Participants were invited to include or exclude any associates (e.g., loved ones) in the consent process.

   Patients were asked to read the consent form and given ample opportunity to have their questions answered. To avoid coercion, the consenting investigator read through a copy of the consent form with the participant, section by section, ensuring the participant understood each section and had an opportunity to ask questions. If at any time the participant indicated they were not interested in participating, the meeting was ended.

   If, after going through the consent form, the participant indicated they wanted to discuss the study with associates or think about participating, the meeting was ended, and the participant was asked to contact the study when they made their decision. If the participant contacted the study in the future for participation, they were invited back to the clinic, and if informed consent was given at that time, study activities began then.

   If the participant indicated they were interested in participating after going through the consent form with the investigator, and the investigator determined the participant had the capacity to

provide informed consent, the participant was asked to provide informed consent at that time. Patients certified their willingness to participate in the study by signing and dating the IRB-approved informed consent document. The subject was given a copy of the consent form.

If any new findings required changes to the informed consent form, the subject was re-consented.

Non-English-speaking subjects were not enrolled in the study because study staff at the time were not certified, prepared, or trained to translate or communicate in any language other than English. The study budget did not allow for the payment of translation services at that time.

3) Study Location:

The study was conducted at Tufts University School of Dental Medicine.

4) Personnel:

Ongoing communication with the IRB was maintained by the PI (Dr. Panos Papaspyridakos).

5) Payment for Participation:

(a) Compensation

$75 gift cards .

(b) Transportation

Free parking pass or a metro card.

(c) Payment and Insurance

Neither the subject nor their insurance company was billed for any study procedures.

6) Study Results:

If interested, study results were presented to a subject upon their request, either in person or via mail, according to their preference, upon completion of the study. A log was kept of these requests.

7) Confidentiality:

To ensure confidentiality of subject information, each subject enrolled in the study was assigned a unique alphanumeric code. Subjects' files were kept in a secure, locked cabinet in a secure room (DHS-1242) when the files were not being reviewed. The information was only shared between the researchers. All HIPAA requirements were followed. All electronic files were kept on a password-protected computer in a secure, locked office (DHS-1246).

(a) Coding:

Each subject was assigned a subject identification number. Alphanumeric identification numbers were assigned sequentially. The full subject identification number consisted of the three letters from the subject's initials and their enrollment number. This was accessible to study personnel only.

(b) Access:

Only study personnel had access to data. Investigators permitted monitoring, audits, and regulatory inspections and provided direct access to study-related documentation.

10) Data Safety Monitoring Plan:

Study personnel monitored this trial for all safety-related issues to determine whether an unreasonable risk to subjects developed. Quality control measures included routine inspection of case report forms, source documents, data tabulations, and tracking of adverse events.

11) New Findings:

Subjects were informed of any significant new findings discovered during the course of the study that might have influenced their continuation and participation in the study. Subjects were told at a study appointment or via telephone of new findings during the study. If new findings required revisions to the ICF, subjects were re-consented.

Record Retention

1) Study Records

The principal investigator (Dr. Panos Papaspyridakos) maintained all study records and documents during the study period. All paper files and documents were kept in a locked file cabinet within a locked room (DHS-1242). Electronic records were kept on a password-protected computer and were accessible only to study personnel.

2) Long Term Retention

The investigator maintained all study records following completion or termination of the study in accordance with state law and institutional policy (at least 7 years after the study was completed or terminated).

Reporting

Unanticipated problems and adverse events were reported per the Tufts MC/TUHS IRB Unanticipated Problem and Adverse Event Reporting Policy.

The IRB was notified of any deviations from the protocol in cases of medical emergencies when changes were necessary to eliminate an apparent immediate hazard to the subject. Progress reports on the investigation were submitted to the IRB at regular intervals, but no less often than yearly, e.g., at continuing review.

Protocol Deviations

No protocol changes or deviations were made without prior agreement from the IRB unless implemented to prevent an immediate hazard to subjects. All other protocol changes or deviations were made by a formal amendment subject to IRB approval. All such changes or deviations were reported to the IRB as they occurred and were included in the final study report.

Study Termination

This study could have been terminated for the following reasons:

- Discovery of unforeseen risks that could jeopardize the dental/physical well-being of subjects.
- Enrollment or recall rates that were not likely to produce sufficient data for evaluation of safety and efficacy.
- Non-compliance with the clinical investigational plan, the Investigator.
- Agreement, applicable FDA regulations, or conditions of approval imposed by the reviewing IRB.

<u>Withdrawal of IRB approval</u>

In the event of study termination, the Principal Investigator (Dr. Panos Papaspyridakos) determined whether subjects needed additional treatment and/or follow-up observation as a result of participation in this trial.

Subject Recruitment/Advertising

Once the study was approved by the IRB, the study team reviewed the step-by-step procedures of each study visit and the IRB-approved recruitment materials to ensure everyone on the study team understood the study procedures. For recruitment to this study, an AxiUm chart record review was performed by the IT department of TUSDM to identify potentially qualifying subjects. Potential participants were called and informed about the single-visit study. Those who agreed to participate came to TUSDM for one single visit. If a potential participant had not replied within 3 weeks, the investigator could call the patient again to gauge their interest.

To incentivize patient participation and compensate for their valuable time, participants were provided with parking coupons, limited T passes, or gift cards upon completion of the study.

All forms of recruitment were submitted for IRB approval prior to use.

Screen failure data were retained by the PI (Dr. Panos Papaspyridakos). Screening ID numbers and demographic information were recorded. Identifiable information was not recorded in the screening log.

Timeline:

- Research protocol and IRB approval: August-December 2023
- Recruiting subjects: January- June 2024
- Clinical examination: January- June 2024
- Data collection and statistical analysis: July 2024
- Manuscript writing: September- December 2024
- Thesis writing and defense: September-December 2024

Results

This study included a sample of 44 individuals. The age of participants varied, with a mean of 66.98 (SD=12.1) years and a range of 32 to 83 years. Twenty individuals (45.5%) identified as female, and twenty-four individuals (54.5%) identified as male. Forty one participants identified as white, two as Asian and one as black. Thirty-nine participants identified as non-Hispanic four as Hispanic and one as African American. Five participants (11.4%) self-reported as a smoker and three participants (6.8%) was observed for self-reported diabetes. None of the participants reported to have undergone jaw irradiation, one participant had a history of cancer, and one reported having used bisphosphonates.

Regarding dental conditions and treatments, the study explored various variables. The majority of the participants (72.7%) reported not using a nightguard, while 27.3% indicated using one. Bruxism, a condition characterized by teeth grinding or clenching, was reported by 25% of the participants, while 75% did not report having the condition. The distribution of opposing dentition among the participants was as follows: 13.1% had natural dentition, 50.8% had implant-supported dentition, 14.8% used removable prosthesis, 19.7% had a combination of teeth and implants, and 1.6% had an implant overdenture.

In terms of specific dental treatments, 67.2% of the prostheses did not have a cantilever, while 32.8% had a cantilever. Among the participants, 52.5% of 32 monolithic zirconia implant-supported fixed complete-arch dental prostheses were made in the maxilla, and 47.5% in the mandible. Regarding prosthesis types, sixty participants (98.4%) had an abutment level prosthesis and only one (1.6%) had an implant level prosthesis. The number of teeth in the participants exhibited little variation, with 95.1% having 12 units, 1.6% having 10 units, 1.6% having 13 units and 1.6% having 14 units. Similarly, the distribution of abutments and implants was peaked, with 85.2% of participants having 6 abutments and 6 implants, 6.6% having 4 abutments and 4 implants, 6.6% having 5 abutments and 5 implants, and only 1.6% having 7 abutments and 7 implants.

The mean duration of prosthesis use was approximately 28.67 months, with considerable variation (SD = 18.32 months). There were four prosthesis failures in this study (93.44% survival rate of the

prosthesis CI), with two prosthesis fractures and two implant failures reported in this study. The Kaplan-Meier curve with a two-sided 95% confidence interval is shown in Figure 10.

Participants experienced very few major complication events (mean= 0.07 events, SD = 0.25), and the majority did not encounter any major complications (median= 0 events). Minor complications were slightly more common (mean= 0.74 events, SD = 1.12), with variability in occurrence (median= 0 event, IQR = 0.0 events to 1.0 events). Combining major and minor complications, the mean total number of complications was 0.8 events (SD = 1.6), with some variability among participants (median = 0 event, IQR = 0.0 events to 1.5 events).

Among the minor technical complications that were found ti-base decementation, loss of access hole material, chipping, and wear of prosthetic screw emerged as the most prevalent, occurring in 13%, 13%, 12%, and 11.5% of cases, respectively. Loosening of abutment did not show in any of the participants. The occurrence of fracture of veneer was also relatively infrequent, affecting only 1.6% of cases, with an overwhelming majority (98.4%) experiencing no such complication. Several other complications, including occlusal wear, and screw loosening, were observed in smaller percentages of 8.2%, and 4.9%, respectively.

The major complications of fracture of implant did not occur in any of the 44 cases (0% for all). However, in the case of fracture of screw, one instance was recorded, representing 2% of the cases, and fracture of framework occurred in 3% of the cases. The study recorded a total of 45 minor complication events and 4 major complication events.

Building on the observed prevalence of complications, further analysis was conducted to explore associations between independent variables and various minor technical complication outcomes. This analysis provided insight into potential factors contributing to minor and major complications. Notably, while loss of access hole material was analyzed, no significant associations were identified. Additionally, statistical analysis could not be performed on certain minor complications and all major complications due to their small or non-existent occurrences, limiting further exploration of these categories.

Analysis revealed several significant associations between independent variables and technical complications. For wear of material, there was a statistically significant positive association between the number of implants and wear of material (OR = 2.99, 95% CI (1.08 - 8.22), p = 0.034). Regarding chipping, there was a statistically significant positive association between follow-up time and chipping (OR = 1.05, 95% CI (1.01 - 1.09), p = 0.009), and there was a statistically significant positive association between the number of implants and chipping (OR = 3.04, 95% CI (1.09 - 8.51), p = 0.034). For wear of the prosthetic screw, there was a statistically significant positive association between the number of implants and wear of the prosthetic screw (OR = 2.95, 95% CI (1.09 - 8.00), p = 0.034). In the case of debonding of the Ti-base, debonding of Ti-base was significantly more likely to occur in subjects identifying as female (OR = 12.66, 95% CI (1.45 - 110.90), p = 0.022), and there was a statistically significant positive association between the number of teeth and debonding of Ti-base (OR = 4.02, 95% CI (1.75 - 9.25), p = 0.001).

There was a statistically significant positive association between follow-up time and minor complications events (OR = 1.02, 95% CI (1.00 - 1.04), p = 0.047), as well as a statistically significant positive association between the number of teeth and minor complications events (OR = 1.44, 95% CI (1.05 - 1.98), p = 0.024) and a statistically significant positive association between the number of implants and minor complications events (OR = 2.20, 95% CI (1.10 - 4.40), p = 0.026). Similarly, there was a statistically significant positive association between the number of implants and minor complications (OR = 2.14, 95% CI (1.02 - 4.51), p = 0.045). There was a statistically significant positive association between follow-up time and total complications events (OR = 1.02, 95% CI (1.00 - 1.04), p = 0.019), a statistically significant positive association between the number of teeth and total complications events (OR = 1.44, 95% CI (1.05 - 1.99), p = 0.025), and a statistically significant positive association between the number of implants and total complications events (OR = 2.65, 95% CI (1.33 - 5.26), p = 0.005). Lastly, there was a statistically significant positive association between follow-up time and total complications (OR = 1.02, 95% CI (1.00 - 1.04), p = 0.033) and a statistically significant positive

association between the number of implants and total complications (OR = 2.65, 95% CI (1.22 - 5.76), p = 0.014).

All significant associations are described above, while other independent variables that did not show significant associations are detailed in Table 7-15 for reference.

Following the bivariate analysis, multivariable logistic regression was performed for the outcome variables **Minor Complications Events**, **Minor Complications**, **Total Complications Events**, and **Total Complications** to account for potential confounding factors. The independent variables included follow-up time, gender, smoking status, jaw location (maxillary or mandibular), nightguard use, and bruxism. Due to small or non-existent occurrences, statistical analysis could not be performed on the other minor complications.

There was a statistically significant positive association between follow-up time and minor complications events (OR = 1.02, 95% CI (1.00 - 1.03), p = 0.033). There was a statistically significant positive association between follow-up time and minor complications (OR = 1.02, 95% CI (1.00 - 1.04), p = 0.017), and minor complications were significantly more likely to occur in subjects identifying as female (OR = 2.38, 95% CI (1.02 - 5.55), p = 0.045). There was a statistically significant negative association between non-smoking and minor complications (OR = 0.16, 95% CI (0.05 - 0.57), p = 0.004), while being in the maxillary jaw was positively associated with minor complications (OR = 1.71, 95% CI (1.17 - 2.50), p = 0.006).

There was a statistically significant positive association between follow-up time and total complications events (OR = 1.02, 95% CI (1.01 - 1.04), p = 0.004). Lastly, there was a statistically significant positive association between follow-up time and total complications (OR = 1.02, 95% CI (1.001 – 1.03), p = 0.042).

The significant associations are outlined above, while non-significant results are presented in Table 17-19.

Seventeen patients had double arch IFCDPs and a total of 355 implants were placed on these 61 edentulous jaws, 189 maxillary, and 166 mandibular implants. In the posterior area, the mean square

surface for the maxillary zirconia IFCDPs, based on 32 prostheses supported by 189 implants, at the posterior abutment cross-sectional area was 26.53 mm^2 (SD=12.95) at the lingual side of the abutment, with a range from 5.05 mm^2 to 74.67 mm^2, and 46.15 mm^2 (SD=21.63) at the buccal side, with a range from 16.13 mm^2 to 109.77 mm^2. At the connector cross-sectional area, the mean square surface was 79.73 mm^2 (SD=23.88), ranging from 27.68 mm^2 to 142.12 mm^2. At the pontic cross-sectional area, the mean square surface was 100.42 mm^2 (SD=25.49), with a range from 53.18 mm^2 to 169.37 mm^2.

The linear measurements in the posterior area of the maxillary zirconia IFCDPs were analyzed for the height and width of various cross-sectional components. The mean height of the lingual side of the abutment was 10.13 mm (SD=2.40), with a range from 5.22 mm to 16.84 mm. The corresponding mean width was 3.42 mm (SD=1.16), ranging from 0.90 mm to 6.98 mm. On the buccal side of the abutment, the mean height was 11.62 mm (SD=2.11), with a minimum of 5.96 mm and a maximum of 17.81 mm. The width of the buccal side of the abutment averaged 4.57 mm (SD=1.63), ranging from 1.18 mm to 10.26 mm. For the connectors, the mean height was 10.12 mm (SD=2.09), with a range of 4.30 mm to 16.38 mm, while the mean width was 9.64 mm (SD=1.63), ranging from 6.07 mm to 13.91 mm. At the pontic region, the mean height was recorded as 10.25 mm (SD=2.39), with a range from 5.19 mm to 16.64 mm, and the mean width was 10.46 mm (SD=1.02), ranging between 7.89 mm and 13.24 mm.

In the anterior area, the mean square surface for the maxillary zirconia IFCDPs at the anterior abutment cross-sectional area was 14.47 mm^2 (SD=6.20) at the lingual side of the abutment, with a range from 5.91 mm^2 to 33.09 mm^2, and 55.32 mm^2 (SD=17.47) at the buccal side, with a range from 25.54 mm^2 to 99.80 mm^2. At the connector cross-sectional area, the mean square surface was 76.76 mm^2 (SD=22.12), ranging from 27.08 mm^2 to 142.12 mm^2. At the pontic cross-sectional area, the mean square surface was 96.04 mm^2 (SD=21.29), with a range from 56.04 mm^2 to 166.10 mm^2.

The linear measurements in the anterior area of the maxillary zirconia IFCDPs were similarly assessed. The mean height of the lingual side of the abutment was 7.85 mm (SD=1.82), with a range of 4.47 mm to 12.78 mm. The mean width was 2.50 mm (SD=0.98), ranging from 1.22 mm to 6.97 mm. On the buccal side of the abutment, the mean height was 13.46 mm (SD=2.18), with a minimum of 7.34 mm

and a maximum of 18.93 mm, while the width averaged 5.53 mm (SD=1.62), ranging from 2.55 mm to 10.48 mm. For the connectors, the mean height was 11.86 mm (SD=2.34), ranging from 5.59 mm to 19.22 mm, and the mean width was 9.56 mm (SD=1.63), with a range from 5.75 mm to 12.76 mm. At the pontic region, the mean height was 13.97 mm (SD=1.55), ranging from 9.25 mm to 18.37 mm, and the mean width was 10.33 mm (SD=1.69), with a range of 6.45 mm to 15.77 mm.

In the posterior area, the mean square surface for the mandibular zirconia IFCDPs, based on 29 prostheses supported by 166 implants, at the posterior abutment cross-sectional area was 27.19 mm^2 (SD=14.31) at the lingual side of the abutment, with a range from 9.99 mm^2 to 75.18 mm^2, and 42.66 mm^2 (SD=20.25) at the buccal side, with a range from 6.91 mm^2 to 117.35 mm^2. At the posterior connector cross-sectional area, the mean square surface was 83.54 mm^2 (SD=23.13), ranging from 21.68 mm^2 to 137.63 mm^2. At the posterior pontic cross-sectional area, the mean square surface was 109.38 mm^2 (SD=20.97), with a range from 53.23 mm^2 to 160.83 mm^2.

The linear measurements of mandibular zirconia IFCDPs were analyzed for the height and width of various cross-sectional components. The mean height of the lingual side of the abutment was 10.61 mm (SD=2.33), with a range from 6.00 mm to 19.47 mm. The corresponding mean width was 3.35 mm (SD=1.29), ranging from 1.38 mm to 10.38 mm. On the buccal side of the abutment, the mean height was 11.92 mm (SD=2.21), with a minimum of 4.96 mm and a maximum of 16.85 mm. The width of the buccal side of the abutment averaged 4.40 mm (SD=1.72), ranging from 0.67 mm to 9.37 mm. For the connectors, the mean height was 11.81 mm (SD=2.50), with a range of 3.19 mm to 18.29 mm, while the mean width was 9.49 mm (SD=1.66), ranging from 6.00 mm to 13.16 mm. At the pontic region, the mean height was recorded as 13.56 mm (SD=2.29), with a range from 5.60 mm to 18.47 mm, and the mean width was 9.78 mm (SD=1.20), ranging between 7.27 mm and 12.81 mm.

In the anterior area, the mean square surface for the mandibular zirconia IFCDPs at the anterior abutment cross-sectional area was 17.02 mm^2 (SD=7.59) at the lingual side of the abutment, with a range from 6.48 mm^2 to 36.01 mm^2, and 57.70 mm^2 (SD=16.05) at the buccal side, with a range from 20.28 mm^2 to 90.54 mm^2. At the connector cross-sectional area, the mean square surface was 86.70 mm^2

(SD=22.12), ranging from 33.11 mm² to 131.91 mm². At the pontic cross-sectional area, the mean square surface was 100.72 mm² (SD=22.21), with a range from 56.13 mm² to 156.78 mm².

The linear measurements of mandibular zirconia IFCDPs were similarly assessed. The mean height of the lingual side of the abutment was 8.17 mm (SD=2.45), with a range of 1.75 mm to 13.86 mm. The mean width was 3.00 mm (SD=1.29), ranging from 1.18 mm to 6.70 mm. On the buccal side of the abutment, the mean height was 14.65 mm (SD=2.58), with a minimum of 6.02 mm and a maximum of 19.20 mm, while the width averaged 5.35 mm (SD=1.68), ranging from 2.43 mm to 9.39 mm. For the connectors, the mean height was 14.25 mm (SD=2.77), ranging from 4.83 mm to 20.07 mm, and the mean width was 9.72 mm (SD=2.01), with a range from 4.34 mm to 13.68 mm. At the pontic region, the mean height was 15.49 mm (SD=2.46), ranging from 9.64 mm to 20.67 mm, and the mean width was 9.68 mm (SD=1.65), with a range of 5.55 mm to 13.36 mm.

Additionally, a detailed fractographic analysis was conducted to further evaluate the structural and dimensional characteristics of the two fractured prostheses. This analysis focused on specific surface area and linear measurements to identify potential contributory factors to the fractures.

Regarding the measurements in the first **fractured maxillary prosthesis** supported by 6 implants, the analysis revealed the following. In the posterior area, the mean square surface for the maxillary zirconia IFCDPs at the posterior abutment cross-sectional area was 28.05 mm² (SD=13.42) at the lingual side of the abutment, with a range from 12.04 mm² to 43.72 mm², and 34.36 mm² (SD=7.56) at the buccal side, with a range from 27.45 mm² to 42.43 mm². At the connector cross-sectional area, the mean square surface was 68.99 mm² (SD=6.93), ranging from 58.85 mm² to 78.40 mm². At the pontic cross-sectional area, the mean square surface was 87.94 mm² (SD=12.49), with a range from 77.77 mm² to 101.89 mm².

The linear measurements of the fractured maxillary zirconia IFCDP were analyzed for the height and width of various cross-sectional components. The mean height of the lingual side of the abutment was 9.26 mm (SD=1.62), with a range from 6.87 mm to 10.49 mm. The corresponding mean width was 3.76 mm (SD=1.29), ranging from 2.43 mm to 5.52 mm. On the buccal side of the abutment, the mean height

was 10.39 mm (SD=1.23), with a minimum of 8.60 mm and a maximum of 11.35 mm. The width of the buccal side of the abutment averaged 4.16 mm (SD=0.72), ranging from 3.50 mm to 4.89 mm. For the connectors, the mean height was 9.10 mm (SD=0.45), with a range of 8.68 mm to 9.76 mm, while the mean width was 8.84 mm (SD=0.60), ranging from 8.07 mm to 9.61 mm. At the pontic region, the mean height was recorded as 10.48 mm (SD=1.00), with a range from 9.85 mm to 11.64 mm, and the mean width was 10.44 mm (SD=0.67), ranging between 9.78 mm and 11.13 mm.

In the anterior area, the mean square surface for the maxillary zirconia IFCDPs at the anterior abutment cross-sectional area was 6.59 mm^2 (SD=0.96) at the lingual side of the abutment, with a range from 5.91 mm^2 to 7.28 mm^2, and 48.69 mm^2 (SD=5.27) at the buccal side, with a range from 44.96 mm^2 to 52.42 mm^2. At the connector cross-sectional area, the mean square surface was 69.76 mm^2 (SD=7.65), ranging from 62.70 mm^2 to 77.89 mm^2. At the pontic cross-sectional area, the mean square surface was 93.21 mm^2 (SD=5.96), with a range from 86.54 mm^2 to 100.43 mm^2.

The linear measurements of the fractured maxillary zirconia IFCDP were similarly assessed. The mean height of the lingual side of the abutment was 4.95 mm (SD=0.26), with a range of 4.77 mm to 5.14 mm. The mean width was 1.80 mm (SD=0.29), ranging from 1.59 mm to 2.01 mm. On the buccal side of the abutment, the mean height was 12.12 mm (SD=0.44), with a minimum of 11.81 mm and a maximum of 12.44 mm, while the width averaged 5.35 mm (SD=0.43), ranging from 4.33 mm to 6.36 mm. For the connectors, the mean height was 11.14 mm (SD=1.36), ranging from 10.25 mm to 12.71 mm, and the mean width was 9.88 mm (SD=0.93), with a range from 8.88 mm to 10.72 mm. At the pontic region, the mean height was 13.46 mm (SD=0.6), ranging from 12.48 mm to 14.07 mm, and the mean width was 11.81 mm (SD=0.79), with a range of 11.09 mm to 13.00 mm.

The fractured maxillary IFCDP fractured in the upper right first premolar (#5) abutment area. The measurements for the lingual side of the abutment were a height of 6.87 mm, a width of 2.43 mm, and a surface area of 12.04 mm^2. For the buccal side of the abutment, the height was 8.60 mm, the width was 3.59 mm, and the surface area was 27.45 mm^2.

When compared to the means of all maxillary prostheses, the lingual side height (6.87 mm) was below the mean of 10.13 mm, and the width (2.43 mm) was below the mean of 3.42 mm. The surface area (12.04 mm^2) was also significantly below the mean of 26.53 mm^2. For the buccal side, the height (8.60 mm) was below the mean of 11.62 mm, the width (3.59 mm) was below the mean of 4.57 mm, and the surface area (27.45 mm^2) was below the mean of 46.15 mm^2. In comparison to the means of the fractured maxillary prosthesis, the lingual side height (6.87 mm) was below the mean of 9.26 mm, the width (2.43 mm) was below the mean of 3.76 mm, and the surface area (12.04 mm^2) was below the mean of 28.05 mm^2. For the buccal side, the height (8.60 mm) was below the mean of 10.39 mm, the width (3.59 mm) is below the mean of 4.16 mm, and the surface area (27.45 mm^2) was below the mean of 34.36 mm^2.

Regarding the measurements in the second **fractured mandibular prosthesis** supported by 7 implants, the analysis revealed the following. In the posterior area, the mean square surface for the mandibular zirconia IFCDPs at the posterior abutment cross-sectional area was 19.97 mm^2 (SD=13.1) at the lingual side of the abutment, with a range from 10.39 mm^2 to 41.47 mm^2, and 37.36 mm^2 (SD=6.36) at the buccal side, with a range from 31.21 mm^2 to 45.50 mm^2. At the posterior connector cross-sectional area, the mean square surface was 32.79 mm^2 (SD=9.26), ranging from 21.68 mm^2 to 45.36 mm^2. At the posterior pontic cross-sectional area, the mean square surface was 78.73 mm^2 (SD=0.00) with no variability noted, also with no observed range.

The linear measurements of the fractured mandibular zirconia IFCDP were analyzed for the height and width of various cross-sectional components. The mean height of the lingual side of the abutment was 9.1 mm (SD=1.57), with a range from 6.98 mm to 11.26 mm. The corresponding mean width was 2.58 mm (SD=0.96), ranging from 1.60 mm to 3.97 mm. On the buccal side of the abutment, the mean height was 10.26 mm (SD=1.19), with a minimum of 9.02 mm and a maximum of 11.95 mm. The width of the buccal side of the abutment averaged 4.96 mm (SD=0.98), ranging from 3.64 mm to 6.30 mm. For the connectors, the mean height was 6.14 mm (SD=2.53), with a range of 3.19 mm to 9.52 mm, while the mean width was 6.96 mm (SD=0.61), ranging from 6.00 mm to 7.72 mm. At the pontic region, the mean

height was recorded as 10.18 mm (SD=0.00), with no variability noted, while the mean width was 8.95 mm (SD=0.00), also with no observed range.

In the anterior area, the mean square surface for the mandibular zirconia IFCDPs at the anterior abutment cross-sectional area was 9.14 mm^2 (SD=1.09) at the lingual side of the abutment, with a range from 8.37 mm^2 to 9.92 mm^2, and 30.39 mm^2 (SD=14.29) at the buccal side, with a range from 20.28 mm^2 to 40.50 mm^2. At the connector cross-sectional area, the mean square surface was 41.08 mm^2 (SD=5.86), ranging from 33.11 mm^2 to 47.15 mm^2. At the pontic cross-sectional area, the mean square surface was 67 mm^2 (SD=9.07), with a range from 56.13 mm^2 to 79.6 mm^2.

The linear measurements of the fractured mandibular zirconia IFCDP were similarly assessed. The mean height of the lingual side of the abutment was 5.72 mm (SD=0.16), with a range of 5.60 mm to 5.84 mm. The mean width was 2.79 mm (SD=0.5), ranging from 2.44 mm to 3.15 mm. On the buccal side of the abutment, the mean height was 9.28 mm (SD=3.57), with a minimum of 6.75 mm and a maximum of 11.81 mm, while the width averaged 4.49 mm (SD=1.29), ranging from 3.58 mm to 5.41 mm. For the connectors, the mean height was 9.56 mm (SD=3.54), ranging from 4.83 mm to 13.24 mm, and the mean width was 6.93 mm (SD=0.68), with a range from 6.13 mm to 7.65 mm. At the pontic region, the mean height was 13.33 mm (SD=1.38), ranging from 11.23 mm to 14.32 mm, and the mean width was 8.38 mm (SD=1.69), ranging from 6.36 mm to 10.13 mm.

The fractured mandibular IFCDP fractured in between the lower right first premolar (#28) and the lower right second premolar (#29) at the connector area. The measurements for the connector at the location of the fracture were a height of 3.96 mm, a width of 6.00 mm, and a surface area of 21.68 mm^2.

When compared to the means of all mandibular prostheses, the connector height (3.96 mm) was below the mean of 11.81 mm, and the width (6.00 mm) was within the lower range of the mean of 9.49 mm. The surface area (21.68 mm^2) was significantly below the mean of 83.54 mm^2. In comparison to the means of the fractured mandibular prosthesis, the connector height (3.96 mm) was below the mean of

6.14 mm, and the width (6.00 mm) was within the range of the mean of 6.97 mm. The surface area (21.68 mm^2) was also below the mean of 32.79 mm^2.

Details regarding the prosthetic space dimensions of the zirconia implant-fixed complete dental prostheses (IFCDPs) are presented in Tables 20–23.

The survey responses, categorized into functional limitations, physical pain, psychological discomfort, physical and psychological disability, social disability, and overall handicap, are detailed below.

The survey assessed functional limitations caused by prosthesis use, focusing on patients' ability to pronounce words and their sense of taste. Regarding speech difficulties, 68.2% of respondents reported never experiencing trouble pronouncing words due to their teeth, mouth, or dentures. However, a minority of patients experienced occasional difficulties (13.6%), with 13.6% reporting this issue hardly ever and 4.5% indicating that it occurred fairly often. For taste-related concerns, 93.2% of patients indicated that their sense of taste had never worsened due to dental problems, with only 6.8% occasionally encountering this issue.

Physical pain associated with prosthesis use was explored through questions on aching and eating discomfort. The majority (75%) reported never having experienced painful aching in the mouth, while 13.6% noted occasional occurrences, and 11.4% hardly ever experienced this discomfort. Similarly, 70.5% of respondents did not find eating uncomfortable due to their prosthesis. However, a smaller proportion experienced eating discomfort occasionally (11.4%), hardly ever (13.6%), or fairly often (4.5%).

Patients were asked about self-consciousness and tension arising from dental issues. Most patients (79.5%) stated they had never been self-conscious because of their prosthesis, with smaller groups reporting occasional (4.5%), hardly ever (4.5%), or frequent (6.8% fairly often; 4.5% very often) experiences of self-consciousness. Tension due to dental issues was less common, with 77.3% reporting

never feeling tense, and a minority indicating occasional (9.1%), hardly ever (6.8%), or frequent (6.8% combined fairly often and very often) tension.

The physical disability dimension assessed dietary satisfaction and interruptions to meals. The majority (79.5%) reported no dietary dissatisfaction due to their prosthesis, while 11.4% occasionally and 6.8% hardly ever experienced this issue. Interruptions to meals were also rare, with 79.5% indicating no disruptions, although 11.4% experienced these issues hardly ever, and a smaller group occasionally (6.8%) or very often (2.3%).

Psychological disability was explored through relaxation difficulties and feelings of embarrassment. Most patients (86.4%) stated they never found it difficult to relax due to dental problems, while a small percentage reported occasional (4.5%), hardly ever (6.8%), or fairly often (2.3%) difficulties. Regarding embarrassment, 79.5% reported no such experiences, with 13.6% occasionally feeling embarrassed and 2.3% each for hardly ever and very often.

Social interactions and occupational disruptions were explored as part of social disability. The majority (90.9%) reported never being irritable with others due to their prosthesis, with 9.1% indicating they hardly ever experienced this issue. Similarly, 90.9% faced no difficulties performing their usual jobs, with 9.1% hardly ever encountering this issue.

The survey's final section addressed broader life satisfaction and functionality. The majority (81.8%) did not feel that life was less satisfying due to their prosthesis, while 9.1% occasionally, 4.5% hardly ever felt this way, 2.3% fairly often, and 2.3% very often. Total inability to function due to prosthesis issues was rarely reported, with 93.2% indicating it never occurred and 4.5% occasionally or hardly ever experiencing such challenges.

Discussion:

In modern dentistry, zirconia has become increasingly prominent due to its exceptional properties. These include biocompatibility, low bacterial adherence, high flexural strength, toughness enabled by the transformation toughening mechanism, and aesthetics. The introduction of CAD/CAM zirconia restorations has brought transformative advancements, particularly in addressing restorative challenges associated with complete-arch implant-supported prostheses. Widely recommended for such restorations, zirconia frameworks offer reliability, especially when fabricated as monolithic zirconia prostheses. By having a uniform composition, monolithic zirconia significantly reduces interface issues, minimizing the risk of fractures and chipping.

Zirconia-based restorations, given their attributes, have emerged as a strong alternative to traditional porcelain-fused-to-metal (PFM) restorations. However, the variety of implant-prosthetic options available makes determining the optimal treatment protocol for edentulous patients a significant challenge for clinicians. Robust, long-term scientific evidence is ideally required to support treatment planning. Comparative studies remain necessary to assess the relative benefits of the different therapeutic approaches available.

The primary objective of this study was to determine the prosthesis survival and complication rates associated with monolithic zirconia implant-supported fixed full dental prostheses (IFCDPs) in completely edentulous patients following minimum 1-year clinical follow-up.

This study included a sample of 44 individuals with a total of 61 monolithic zirconia implant-supported fixed full dental prosthesis (IFCDPs) arches. The participants had a mean age of 67.07 years, ranging from 32 to 83 years. Additionally, the mean duration of prosthesis use was approximately 28.67 months. Our research contributes significant insights into the technical complications associated with dental prostheses, offering opportunities for enhanced patient care and refined treatment approaches.

In this study, minor complications were defined as those that could be managed and repaired intraorally or chairside by the clinician, while major complications required a more extensive approach by the clinician in the dental chair to address or repair the issue.

The findings indicated that major complications were rare among participants, with the majority not experiencing any. Minor complications, while slightly more frequent, exhibited some variability. Overall, the combined incidence of major and minor complications was relatively low, with differences noted across participants.

Regarding minor complications, the most common technical complications included chipping, ti-base decementation, loss of access hole material, and wear of prosthetic screw. Loosening of abutment was not observed in any participant, representing a positive outcome. Fracture of veneer was relatively uncommon, with most participants unaffected. Other minor complications, such as screw loosening, and occlusal wear, occurred in smaller proportions.

In this study, material **chipping** was observed in 12% of cases (7 out of 61 arches). The occurrences were primarily located on the incisal edges or around the ti-bases. Additionally, a single fracture of the veneered porcelain was documented. Both types of complications were categorized as minor complications, as the prostheses required repair and polishing rather than complete replacement. A similar study conducted by Tischler et al. showed no instances of chipping in the veneered material, as it was veneered with gingival porcelain and restricted to non-load-bearing functions. [39] Comparable results were reported by Bidra et al., who observed no issues when porcelain was limited to the gingival surface [8]. Thompson et al. found that applying veneering porcelain to facial surfaces resulted in minor chipping.[43] When comparing our findings to those of Pozzi et al., Papaspyridakos & Lal, Bidra et al., and Gonzalez et al., similar observations were made regarding chipping of the veneered material on the facial aspect of the teeth. [2, 21, 48, 49] To minimize the risk of chipping or fractures, it is advised to refrain from facial cutback or veneering with porcelain on the facial surface. Alternatively, using a monolithic prosthesis or restricting the veneering material to the gingival surface is recommended. A positive

association was found between follow-up time and the number of implants. Bidra et al. supported these findings by noting that chipping prevalence increased over time due to occlusal wear and mechanical fatigue, aligning with this study's findings.[48] However, no reviewed articles examined the relationship between the number of implants and chipping, underscoring the novelty of this observation.[49] Notably, no previous studies have documented material chipping around the ti-bases; however, our study identified such occurrences in the results.

Additionally, another minor technical complication was identified. The findings revealed that **debonding of the ti-bases** occurred in 13% of cases, with a total of 8 incidents documented. Tischler et al. noted a debonding occurrence involving one ti-base out of 191 prosthesis cases.[39] Similarly, a systematic review conducted by Abdulmajeed et al. found that among the evaluated prosthetic cases, a single ti-base showed evidence of debonding.[35] Conversely, the results of this study revealed a greater frequency of debonding incidents. Additionally, Bidra et al. carried out a study involving 2039 zirconia prostheses. Within the study, at least 319 prostheses were monitored for a minimum period of three years in a clinical environment. The findings showed that six prostheses encountered debonding of the Ti-bases, while three additional prostheses were returned due to fractures of the Ti-bases.[8] No instances of ti-base fractures were identified in this study. Moreover, a study conducted by Gonzalez et al. documented two instances of Ti-base debonding, which ranked as the second most frequent technical complication observed in their research.[2]

Gonzalez et al. highlighted several factors that could lead to Ti-base debonding, including insufficient bonding properties of the zirconia surface, limited space for the cement film thickness, inadequate light diffusion through zirconia for activating dual-cured luting agents, and the lack of resistance or improper form of the metal insert itself.[2] To minimize the risk of debonding, Bidra et al. recommended following the manufacturer's guidelines. This involves using titanium cylinders provided by the implant manufacturer, which are bonded to zirconia, thereby establishing a metal-to-metal interface over the implants or abutments.[8] Female subjects were more likely to experience this complication compared to male, while a positive association was observed with the number of teeth.

Gender-specific differences have not been widely addressed in the literature, but factors such as bone quality may contribute to these findings. Similarly, the relationship between the number of teeth and Ti-base debonding appears to be a novel contribution.[21, 43]

When comparing our study's findings on the **loss of access hole material**, Carames et al. reported a similar outcome. In their research, this issue was also noted as one of the most frequent technical complications, where they had a large sample size and a long follow-up period.[74] There were no significant associations recorded from the study.

In the 61 arches examined, additional complications were noted, but in smaller proportions. Screw loosening was identified in 4.9% of cases, while wear of prosthetic screw was reported in 11.5%, representing 3 and 7 incidents, respectively. A comparison of our study's findings on screw loosening with those of Carames et al. revealed similar results. In their research, screw loosening was likewise identified as a prevalent technical complication.[74] No other study has documented a complication involving the wear of the prosthetic screw. The study revealed a positive association with the number of implants. There were no other studies that mentioned any associations of the number of implants with wear of prosthetic screw or screw loosening.

Notably, the specific issue of occlusal wear has, to our knowledge, not been documented in previous studies. However, evaluating occlusal wear presented certain challenges, as distinguishing between natural wear and prior adjustments made for occlusal purposes proved difficult. For **wear of material**, this study identified a statistically significant positive association between the number of implants and wear of material. However, no similar associations were reported in the reviewed literature. Existing studies primarily focus on prosthetic materials and occlusal forces as contributors to wear, but the influence of implant number has not been explored, making this a novel finding.[21, 39] Additionally, there were no significant associations with factors like bruxism or the use of nightguards. The wear was most commonly noticed when opposing the natural dentition.

There were no occurrences of "Loosening of Abutment" reported among the participants, indicating a positive outcome. Nevertheless, it is important to acknowledge that other studies have reported cases of abutment loosening. For example, Abdulmajeed et al. reported one instance of a loose abutment in their systematic review of prosthetic cases. Similarly, Bidra et al.'s analysis of 285 prosthetic cases identified two occurrences of loose abutments. [48] The underlying reasons or explanations for these occurrences were not discussed within the scope of this study. However, our findings indicate that the frequency of minor technical complications was relatively low and consistent with reports in the existing literature.

The study evaluated major technical complications, including fracture of an abutment, fracture of framework, fracture of implant, and fracture of screw. Most cases were free of these complications, apart from a few instances of fracture of screw and fracture of framework.

In this study, a single case of screw fracture was documented and resolved promptly in the clinic by replacing the broken screw with a new one. This incident occurred in a patient who had been using the prosthesis for five years. Interestingly, Tischler et al. documented two cases of screw fractures in their study, despite utilizing a larger sample size and conducting a longer follow-up period. [39] Compared to their findings, our study reported a lower frequency of such occurrences.

Our study did not observe any instances of abutment fractures. However, in comparable studies, Bidra et al.'s systematic review reported two cases of fractured abutments [48], while Abdulmajeed documented a single case of abutment fracture [35].

Framework or implant fractures are critical contributors to prosthesis failure. In our research, we observed two instances of framework fractures. However, the overall occurrence of major technical complications was significantly low, with only two prostheses requiring replacement due to fractures. Our study highlights a significantly reduced occurrence of major technical complications, achieving a survival rate of 93.44% for the 61 prostheses over an average usage period of approximately 28.67 months. When comparing these findings to existing literature, our study reported a higher survival rate, with only two prostheses requiring replacement due to fractures and the other two were implant failures. These findings

are consistent with similar studies by Barootchi et al., and Papaspyridakos et al, where both studies documented two cases of zirconia fractures, reporting a survival rate of 93.7% and 98.6%, respectively.[10] Similarly, a study by Tischler et al. analyzing 191 prostheses found that three zirconia full-arch fixed implant prostheses had to be remade because of implant failures, while one prosthesis required replacement due to fracture, representing an incidence rate of 0.6%. This study reported a 4-year cumulative survival rate (CSR) of 93.44%. [39] Moreover, a study by Papaspyridakos et al. reported a 100% survival rate over a 4-year follow-up period. [21]

Limmer et al. conducted a study with a follow-up period comparable to ours, reporting a prosthesis survival rate of 88% within one year. Their findings showed that two prostheses required replacement due to fractures, while another two were lost due to implant failure. The study emphasized that fractures might be influenced by several factors, including cantilever length, anterior-posterior (A-P) spread, restorative dimensions, and the material properties of zirconia, which encompass a range of variables. [75]

Tirone et al.[52] reported a prosthesis fracture rate of 4.4%, with 8 out of 180 IFCDPs fracturing over a 7-year follow-up period. Short-term private practice studies with 1- to 2-year follow-ups revealed no complications in 115 monolithic zirconia IFCDPs and 26 modified monolithic zirconia IFCDPs, respectively.[57, 58] Pozzi[49] documented no fractures in 24 zirconia IFCDPs with follow-ups extending up to 12 years. Bidra et al.[8] observed five fractures in a large cohort of 2039 zirconia IFCDPs, with contributing factors such as inadequate dimensions, limited prosthetic space, and proximity to implant abutments.

Additionally, a systematic review by Al-Tarawneh et al.[41] emphasized favorable outcomes with monolithic zirconia IFCDPs but highlighted the risk of underreporting complications such as framework and prosthesis fractures. The review also pointed to the need for well-designed, low-bias, long-term studies to derive stronger conclusions. Despite this, current data indicate that monolithic zirconia prostheses perform better than metal-acrylic resin and metal-ceramic options, which have higher rates of technical complications.[10, 17-19, 54, 55, 76, 77]

The findings of this study reveal several significant associations between variables and various complications in implant-supported full-arch fixed dental prostheses, which provide critical insights for both clinical practice and future research. These findings are discussed in light of the existing literature to contextualize their implications.

For **minor complications events**, significant positive associations were observed with follow-up time, the number of teeth, and the number of implants. However, the influence of the number of teeth and implants is not well documented, making these associations unique.[49, 74]

For **the minor complications outcome**, significant positive associations were found with the number of implants. However, the link between implant number and minor complications remains relatively unexplored in the literature.

For **total complications events**, positive associations were observed with follow-up time, the number of teeth, and the number of implants. Papaspyridakos et al. further confirmed that longer follow-up durations correlate with increased complication rates, particularly with respect to implant-supported prostheses.[54]

Finally, for **total complications**, follow-up time, and the number of implants were all significant. Papaspyridakos et al. reinforced the association between longer follow-up time and increased complications. However, no reviewed articles examined the relationship between the number of implants and total complications, underscoring the novelty of this observation.

These findings corroborate some existing evidence while introducing new associations, particularly regarding implant number and its relationship with various complications. These findings underscore the importance of individualized treatment planning and the need for further studies to validate these observations and explore underlying mechanisms.

Building upon the bivariate analysis findings, the multivariable analysis provided a more nuanced understanding of the relationships between independent variables and the outcomes of interest by accounting for potential confounding factors. These findings revealed significant associations that further elucidate the complex interplay of factors contributing to complications in implant-supported full-arch

fixed dental prostheses. Below, the results of the multivariable analysis are discussed in light of the existing literature.

For **minor complications events**, this study identified a statistically significant positive association with follow-up time. This aligns with findings from Papaspyridakos et al., who reported that longer follow-up durations were associated with higher rates of mechanical complications, including minor failures, supporting the notion that extended observation periods naturally allow for the emergence of more issues.[54]

For minor complications, follow-up time remained a significant predictor, consistent with Pozzi et al., who noted that longer follow-up durations increased the prevalence of minor complications in implant-supported prostheses.[49] Gender was also found to be a significant factor, with females being more likely to experience minor complications. Although gender-specific differences are underexplored in the literature, factors such as hormonal influences and bone quality differences may play a role and merit further investigation.[35] Interestingly, smoking was positively associated with minor complications, with non-smokers showing significantly lower odds of experiencing minor complications. This finding aligns with the established body of evidence highlighting smoking as a risk factor for implant-related complications.[39] Additionally, maxillary prostheses were more likely to experience minor complications than mandibular ones. This aligns with findings by Tischler et al., who reported higher complication rates in maxillary restorations due to differences in bone density and load distribution.[74]

In the context of **total complications events**, follow-up time was again positively associated. This finding is supported by Papaspyridakos et al., who similarly observed that extended follow-up durations correlated with higher complication rates in zirconia implant-supported prostheses.[49, 54]

For **total complications**, follow-up time was again positively associated. This finding is again supported by Papaspyridakos et al., who similarly observed that extended follow-up durations correlated with higher complication rates in zirconia implant-supported prostheses.[49, 54]

The multivariable analysis findings extend our understanding of the factors associated with complications in implant-supported prostheses. While some associations align with existing evidence,

others introduce novel insights, particularly regarding gender, smoking, and follow-up time. These findings highlight the importance of individualized treatment planning and underscore the need for further research to validate these associations and explore their underlying mechanisms.

The impact of factors such as restricted prosthetic dimensions, insufficient restorative space, and the material characteristics of zirconia on prosthesis performance underscores the need for further investigation into specific prosthesis dimensions. Analyzing these variables, especially the thickness and cross-sectional surface areas of zirconia frameworks, may offer valuable insights into their contribution to technical complications, including catastrophic fractures.[54] Thompson et al, emphasizes the importance of factors such as occlusal vertical restorative space and framework thickness.[43] This study provides valuable and novel insights into the surface area dimensions of zirconia implant-fixed complete dental prostheses (IFCDPs), a parameter not directly explored in much of the existing literature.

Regarding subjective mean linear measurements for zirconia IFCDPs, the present study reported a mean **posterior connector height** of 10.12 mm for the maxillary IFCDPs and 11.81 mm for the mandibular IFCDPs. When compared to Papaspyridakos et al., who reported mean posterior connector heights of 9.72 mm for maxillary IFCDPs and 11.86 mm for mandibular ones, this study's findings were slightly similar for both arches. Tischler et al., on the other hand, reported a slightly larger linear measurements, ranging between 11 mm and 12 mm, which aligns closely with the mandibular findings from this study but exceeds the maxillary measurements. These variations may reflect differences in prosthetic design philosophies, fabrication methods, or sample characteristics across studies.[39, 54]
The mean **posterior lingual side surface area** of maxillary prostheses was 26.53 mm^2, and the **buccal side** was 46.15 mm^2, with a **connector surface area** of 79.73 mm^2. These detailed measurements establish new benchmarks for evaluating prosthesis design and potential risk factors for structural failure.

When compared to the findings of Papaspyridakos et al.[54], who measured similar parameters except for pontic dimensions, this study observed larger mean **posterior abutment buccal side surface areas** (46.15 mm^2 in this study vs. 34.19 mm^2 in their findings) and **connector surface areas** (79.73 mm^2 in this study vs. 65.31 mm^2 reported by Papaspyridakos et al.). The **posterior lingual side surface**

areas were comparable (26.53 mm² in this study vs. 25.18 mm² in their study).[54] These differences suggest potential design variations that may influence the mechanical performance of zirconia IFCDPs. Notably, Papaspyridakos et al. also emphasized the critical role of connector dimensions in structural durability, consistent with this study's findings, but they did not measure pontic dimensions, further distinguishing the scope of this research.[54]

The fractured prostheses in this study further illustrate the importance of structural dimensions. In the maxillary fractured prosthesis, the abutment lingual and buccal surface areas of the fracture site was significantly reduced to 12.04 mm² and 27.45 mm², respectively compared to a mean of abutment lingual and buccal surface areas 26.53 mm² and 46.16 mm², respectively in intact prostheses.

Similarly, in the mandibular fractured prosthesis, the posterior connector surface area of the fracture site was significantly reduced to 21.68 mm², compared to a mean of 79.73 mm² in intact prostheses, emphasizing that insufficient connector size and height are critical risk factors for structural failure. Papaspyridakos et al.'s fractured prostheses surface areas were within the range of their intact prostheses. However, they mentioned that fractures often occur at structurally weak points, such as connectors, even when other dimensions appear sufficient.[54]

While other studies, such as those by Kim et al.[51] and Park et al.[50], highlighted the impact of material properties and thickness on fracture resistance, they did not specifically measure surface areas. Tischler et al.[8]and Durkan et al.[46] focused on prosthesis survival and stress distribution, respectively, without delving into detailed structural dimensions. The comparison with Papaspyridakos et al., however, underscores the relevance of connector and abutment surface areas in enhancing the longevity and structural integrity of zirconia IFCDPs.[54]

This study fills a gap in the literature by offering the first detailed measurements of surface areas in zirconia IFCDPs, providing a foundation for future research to explore how these dimensions interact with clinical loading conditions and material properties. These findings have the potential to inform design improvements that enhance prosthesis longevity and reduce the risk of fractures. No clinical recommendation currently exists for the zirconia IFCDPs.

Building upon the analysis of complications and dimension measurements, this study also aimed to explore secondary outcomes related to patient satisfaction and quality of life. Understanding these parameters is essential to provide a more comprehensive evaluation of the long-term success and clinical implications of IFCDPs. By integrating these patient-centered outcomes, the study contributes to a holistic understanding of how IFCDPs impact not only mechanical and structural aspects but also the overall well-being and daily experiences of patients.

The results of the patient survey conducted in this study align closely with findings from previous studies by Al-Tarawneh et al.[44] and Limmer et al.[75], both of which evaluated the clinical performance and patient-centered outcomes of full-arch implant-supported zirconia prostheses. These studies provide valuable context for interpreting the survey findings, particularly regarding functional satisfaction, psychological and social impacts, and overall quality of life.

Functional Satisfaction

In this study, a significant proportion of patients reported no difficulties with speech (68.2%) or taste (93.2%), highlighting the functional reliability of zirconia prostheses. Similarly, Al-Tarawneh et al.[44] and Limmer et al.[75] observed high functional satisfaction with monolithic zirconia prostheses. Al-Tarawneh et al. specifically noted that over 90% of participants rated chewing ability and phonetics positively [44], while Limmer et al. reported significant improvements in Oral Health Impact Profile (OHIP-49) subscale scores related to functional limitations.[75] These findings reinforce that zirconia prostheses effectively restore critical oral functions, contributing to improved patient satisfaction.

Physical Pain and Discomfort

The survey results revealed that 75% of patients experienced no aching pain, and 70.5% reported no eating discomfort. Similarly, both Al-Tarawneh et al. and Limmer et al. documented substantial reductions in physical pain following prosthesis placement. Al-Tarawneh et al. observed minimal reports of discomfort related to their zirconia prostheses [44], while Limmer et al. highlighted significant declines in

OHIP-49 scores associated with physical pain and discomfort over a 12-month period. The consistency of these findings underscores the biocompatibility and comfort provided by zirconia prostheses.[75]

Psychological and Social Impact

In this study, 79.5% of patients reported no self-consciousness, and 90.9% indicated no irritability or occupational disruptions due to their prostheses. These findings align with those of Al-Tarawneh et al., who reported high aesthetic satisfaction among participants, a critical factor in reducing self-consciousness and enhancing social confidence.[44] Limmer et al. also documented significant improvements in OHIP-49 subscales related to psychological discomfort and social disability, particularly within the first six months after prosthesis placement.[75] Both studies emphasize the transformative impact of zirconia prostheses on psychological well-being and social integration.

Complications and Maintenance

While the survey in this study did not emphasize complications, Limmer et al.[75] reported a low overall complication rate, with the most common issue being chipping of opposing denture teeth. Al-Tarawneh et al. similarly noted that monolithic zirconia prostheses exhibited fewer complications compared to layered zirconia or alternative materials.[44] The findings from both studies suggest that zirconia prostheses, when properly designed and maintained, are durable and require minimal intervention, contributing to long-term patient satisfaction.

Overall Quality of Life

This study found that 81.8% of patients experienced no reduction in life satisfaction due to their prostheses. Al-Tarawneh et al. similarly highlighted high patient-reported satisfaction levels with functional, aesthetic, and psychological outcomes.[44] Limmer et al. demonstrated profound improvements in OHIP-49 severity and extent scores, with mean reductions of 76.8 and 16.3 points, respectively, over 12 months. These findings collectively affirm that zirconia prostheses significantly enhance overall quality of life by addressing both functional and aesthetic concerns.[75]

The comparison between this study's survey results and the findings of Al-Tarawneh et al. (2023)[44] and Limmer et al. (2014)[75] highlights the substantial benefits of monolithic zirconia prostheses in improving patient satisfaction and oral health-related quality of life. Across all studies, patients consistently reported high satisfaction levels, minimal functional limitations, and significant psychological and social improvements. The durability and aesthetic advantages of zirconia further reinforce its suitability as a material for full-arch implant-supported prostheses, providing a reliable and patient-centered solution for edentulous individuals.

Limitations:

The study has several limitations that should be considered. Although the mean follow-up duration of 28.67 months provided valuable insights, longer follow-up periods are necessary to comprehensively evaluate the long-term survival and complication rates of IFCDPs. The reliance on self-reported data, such as smoking habits and quality-of-life measures, introduces potential recall bias and inaccuracies. Additionally, the participant pool was predominantly non-Hispanic white individuals, limiting the diversity of the sample and its generalizability to broader populations. Certain clinical variables, such as jaw irradiation or bisphosphonate use, were rare or absent, restricting the ability to analyze their potential impact. Small or non-existent occurrences for some minor and major complications further limited the robustness of statistical analyses. The cross-sectional measurements captured at specific time points may not account for dynamic changes in prosthesis dimensions over time due to wear or material fatigue. Furthermore, the subjective nature of quality-of-life measures may not fully reflect the psychological and social impact of prosthesis use. Lastly, as a single-center study, the findings may not be fully generalizable to other clinical settings or geographic regions.

Future Recommendations:

To build upon the findings of this study, future research should aim to include larger and more diverse participant populations to enhance the generalizability of results across different demographics and clinical conditions. Longer follow-up periods are recommended to provide a comprehensive understanding of the long-term survival and complication rates of IFCDPs, including late-stage technical and biological complications. Incorporating advanced imaging and biomechanical testing, such as finite element analysis, could offer deeper insights into stress distribution, wear, and failure mechanisms of prostheses, particularly in high-risk patients.

Further studies should also focus on underrepresented clinical variables, such as the effects of jaw irradiation, bisphosphonate use, and systemic health conditions like diabetes, to better understand their influence on prosthesis outcomes. Evaluating the impact of dynamic changes in prosthesis dimensions over time due to wear or material fatigue could provide valuable information for

improving prosthesis design. Additionally, standardized and objective methods for assessing quality-of-life outcomes are needed to complement subjective survey data, offering a more robust evaluation of the psychological and social impacts of prosthesis use.

Lastly, multicenter studies conducted in various geographic regions and healthcare settings would enhance the external validity of findings and ensure that treatment recommendations are applicable across diverse populations and clinical contexts. By addressing these areas, future research can contribute to optimizing the design, functionality, and patient satisfaction associated with IFCDPs.

Conclusion:

The overall prosthesis survival rate of 93.44% (2 fractures and 2 implant failures) over an average follow-up period of 28.67 months highlights the reliability of IFCDPs in restoring dental function for edentulous patients. While the prevalence of major complications was low, minor technical issues such as ti-base decementation, chipping, loss of access hole material, and wear of prosthetic screw were more common, emphasizing the importance of regular maintenance and monitoring. Structural analysis further revealed associations between complication rates and factors such as the number of implants and follow-up time, which have practical implications for treatment planning.

The study also highlighted the role of prosthetic dimensions in potential failure risks. Fractographic analysis of failed prostheses demonstrated that reduced height, width, and surface area at critical cross-sectional components, such as connectors and abutments, might contribute to fractures. These findings underscore the need for meticulous design and material considerations to optimize prosthesis performance.

In terms of patient-reported outcomes, the majority experienced minimal disruptions to their quality of life, with favorable results reported across functional, physical, psychological, and social domains. However, occasional discomfort and challenges were noted among a small subset of participants, suggesting the importance of personalized care and communication during treatment.

The results of this study provide evidence-based guidance for improving the design, longevity, and patient satisfaction of IFCDPs. Future research should aim to explore the impact of additional variables, such as advanced material technologies and longer follow-up periods, to further enhance outcomes for patients with IFCDPs.

REFERENCES

1. Douglass CW, Shih A, Ostry L. Will there be a need for complete dentures in the United States in 2020? J Prosthet Dent 2002;87(1):5-8.

2. Gonzalez-Gonzalez I, deLlanos-Lanchares H, Brizuela-Velasco A, et al. Complications of Fixed Full-Arch Implant-Supported Metal-Ceramic Prostheses. Int J Environ Res Public Health 2020;17(12).

3. Papaspyridakos P, Bordin TB, Kim YJ, et al. Technical Complications and Prosthesis Survival Rates with Implant-Supported Fixed Complete Dental Prostheses: A Retrospective Study with 1- to 12-Year Follow-Up. J Prosthodont 2020;29(1):3-11.

4. Wong CKK, Narvekar U, Petridis H. Prosthodontic Complications of Metal-Ceramic and All-Ceramic, Complete-Arch Fixed Implant Prostheses with Minimum 5 Years Mean Follow-Up Period. A Systematic Review and Meta-Analysis. J Prosthodont 2019;28(2):e722-e35.

5. Simon H, Yanase RT. Terminology for implant prostheses. Int J Oral Maxillofac Implants 2003;18(4):539-43.

6. Branemark PI. Osseointegration and its experimental background. J Prosthet Dent 1983;50(3):399-410.

7. Mericske-Stern RD, Taylor TD, Belser U. Management of the edentulous patient. Clin Oral Implants Res 2000;11 Suppl 1:108-25.

8. Bidra AS, Tischler M, Patch C. Survival of 2039 complete arch fixed implant-supported zirconia prostheses: A retrospective study. J Prosthet Dent 2018;119(2):220-24.

9. Brennan M, Houston F, O'Sullivan M, O'Connell B. Patient satisfaction and oral health-related quality of life outcomes of implant overdentures and fixed complete dentures. Int J Oral Maxillofac Implants 2010;25(4):791-800.

10. Barootchi S, Askar H, Ravida A, et al. Long-term Clinical Outcomes and Cost-Effectiveness of Full-Arch Implant-Supported Zirconia-Based and Metal-Acrylic Fixed Dental Prostheses: A Retrospective Analysis. Int J Oral Maxillofac Implants 2020;35(2):395-405.

11. Bozini T, Petridis H, Garefis K, Garefis P. A meta-analysis of prosthodontic complication rates of implant-supported fixed dental prostheses in edentulous patients after an observation period of at least 5 years. Int J Oral Maxillofac Implants 2011;26(2):304-18.

12. Purcell BA, McGlumphy EA, Holloway JA, Beck FM. Prosthetic complications in mandibular metal-resin implant-fixed complete dental prostheses: a 5- to 9-year analysis. Int J Oral Maxillofac Implants 2008;23(5):847-57.

13. Mackert J, El-Shewy M, Pannu D, Schoenbaum T. Prosthetic complications and survival rates of metal-acrylic implant fixed complete dental prostheses: A retrospective study up to 10 years. J Prosthet Dent 2022.

14. English CE. Biomechanical concerns with fixed partial dentures involving implants. Implant Dent 1993;2(4):221-42.

15. Davis DM, Packer ME, Watson RM. Maintenance requirements of implant-supported fixed prostheses opposed by implant-supported fixed prostheses, natural teeth, or complete dentures: a 5-year retrospective study. Int J Prosthodont 2003;16(5):521-3.

16. Papaspyridakos P, Chen CJ, Chuang SK, Weber HP, Gallucci GO. A systematic review of biologic and technical complications with fixed implant rehabilitations for edentulous patients. Int J Oral Maxillofac Implants 2012;27(1):102-10.

17. Chochlidakis K, Einarsdottir E, Tsigarida A, et al. Survival rates and prosthetic complications of implant fixed complete dental prostheses: An up to 5-year retrospective study. J Prosthet Dent 2020;124(5):539-46.

18. Papaspyridakos P, Bordin TB, Natto ZS, et al. Double Full-Arch Fixed Implant-Supported Prostheses: Outcomes and Complications after a Mean Follow-Up of 5 Years. J Prosthodont 2019;28(4):387-97.

19. Papaspyridakos P, Bordin TB, Natto ZS, et al. Complications and survival rates of 55 metal-ceramic implant-supported fixed complete-arch prostheses: A cohort study with mean 5-year follow-up. J Prosthet Dent 2019;122(5):441-49.

20. Miyazaki T, Nakamura T, Matsumura H, Ban S, Kobayashi T. Current status of zirconia restoration. J Prosthodont Res 2013;57(4):236-61.

21. Papaspyridakos P, Lal K. Computer-assisted design/computer-assisted manufacturing zirconia implant fixed complete prostheses: clinical results and technical complications up to 4 years of function. Clin Oral Implants Res 2013;24(6):659-65.

22. Zhang Y, Lawn BR. Novel Zirconia Materials in Dentistry. J Dent Res 2018;97(2):140-47.

23. Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. Biomaterials 1999;20(1):1-25.

24. Manicone PF, Rossi Iommetti P, Raffaelli L. An overview of zirconia ceramics: basic properties and clinical applications. J Dent 2007;35(11):819-26.

25. Denry I, Kelly JR. State of the art of zirconia for dental applications. Dent Mater 2008;24(3):299-307.

26. Alghazzawi TF, Lemons J, Liu PR, et al. Influence of low-temperature environmental exposure on the mechanical properties and structural stability of dental zirconia. J Prosthodont 2012;21(5):363-9.

27. Denry IL, Holloway JA. Microstructural and crystallographic surface changes after grinding zirconia-based dental ceramics. J Biomed Mater Res B Appl Biomater 2006;76(2):440-8.

28. Pittayachawan P, McDonald A, Petrie A, Knowles JC. The biaxial flexural strength and fatigue property of Lava Y-TZP dental ceramic. Dent Mater 2007;23(8):1018-29.

29. Guess PC, Att W, Strub JR. Zirconia in fixed implant prosthodontics. Clin Implant Dent Relat Res 2012;14(5):633-45.

30. Sailer I, Philipp A, Zembic A, et al. A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions. Clin Oral Implants Res 2009;20 Suppl 4:4-31.

31. Larsson C, Vult von Steyern P, Sunzel B, Nilner K. All-ceramic two- to five-unit implant-supported reconstructions. A randomized, prospective clinical trial. Swed Dent J 2006;30(2):45-53.

32. Christel P, Meunier A, Heller M, Torre JP, Peille CN. Mechanical properties and short-term in-vivo evaluation of yttrium-oxide-partially-stabilized zirconia. J Biomed Mater Res 1989;23(1):45-61.

33. Mundhe K, Jain V, Pruthi G, Shah N. Clinical study to evaluate the wear of natural enamel antagonist to zirconia and metal ceramic crowns. J Prosthet Dent 2015;114(3):358-63.

34. Scarano A, Piattelli M, Caputi S, Favero GA, Piattelli A. Bacterial adhesion on commercially pure titanium and zirconium oxide disks: an in vivo human study. J Periodontol 2004;75(2):292-6.

35. Abdulmajeed AA, Lim KG, Narhi TO, Cooper LF. Complete-arch implant-supported monolithic zirconia fixed dental prostheses: A systematic review. J Prosthet Dent 2016;115(6):672-77 e1.

36. Larsson C, Vult von Steyern P, Nilner K. A prospective study of implant-supported full-arch yttria-stabilized tetragonal zirconia polycrystal mandibular fixed dental prostheses: three-year results. Int J Prosthodont 2010;23(4):364-9.

37. Papaspyridakos P, Vazouras K, Gotsis S, et al. Complete digital workflow for prosthesis prototype fabrication with double digital scanning: A retrospective study with 45 edentulous jaws. J Prosthodont 2023;32(7):571-78.

38. Chochlidakis K, Romeo D, Ercoli C, Papaspyridakos P. Complete Digital Workflow for Prosthesis Prototype Fabrication with the Double Digital Scanning (DDS) Technique: A Prospective Study on 16 Edentulous Maxillae. J Prosthodont 2022;31(9):761-65.

39. Tischler M, Patch C, Bidra AS. Rehabilitation of edentulous jaws with zirconia complete-arch fixed implant-supported prostheses: An up to 4-year retrospective clinical study. J Prosthet Dent 2018;120(2):204-09.

40. Carames J, Marques D, Malta Barbosa J, et al. Full-arch implant-supported rehabilitations: A prospective study comparing porcelain-veneered zirconia frameworks to monolithic zirconia. Clin Oral Implants Res 2019;30(1):68-78.

41. AlTarawneh S, Thalji G, Cooper L. Full-arch implant-supported monolithic zirconia fixed dental prostheses: An updated systematic review. Int J Oral Implantol (Berl) 2021;14(1):13-22.

42. Tang Y, Yu H, Wang J, Qiu L. Implant Survival and Complication Prevalence in Complete-Arch Implant-Supported Fixed Dental Prostheses: A Retrospective Study with a Mean Follow-up of 5 Years. Int J Oral Maxillofac Implants 2023;38(1):84-93.

43. Thompson J, Schoenbaum TR, Pannu D, Knoernschild K. Survival analysis of zirconia implant-supported, fixed complete dentures: A 5-year retrospective cohort study. J Prosthet Dent 2023.

44. Al-Tarawneh S, Thalji G, Shonberg D, Fayz L, Cooper L. Retrospective Cohort Evaluation of Full-Arch Zirconia Implant-Supported Fixed Prostheses. Int J Oral Maxillofac Implants 2023;38(2):381-90.

45. Tartaglia GM, Farronato M, Sforza C, Bidra AS. Implant-Supported Immediately Loaded Complete Arch Rehabilitations with a Mean Follow-up of 10 Years: A Prospective Clinical Study. J Prosthodont 2019;28(9):951-57.

46. Durkan R, Oyar P, Deste G. Effects of Cantilever Length and Implant Inclination on the Stress Distribution of Mandibular Prosthetic Restorations Constructed from Monolithic Zirconia Ceramic. Int J Oral Maxillofac Implants 2020;35(1):121-29.

47. Le M, Papia E, Larsson C. The clinical success of tooth- and implant-supported zirconia-based fixed dental prostheses. A systematic review. J Oral Rehabil 2015;42(6):467-80.

48. Bidra AS, Rungruanganunt P, Gauthier M. Clinical outcomes of full arch fixed implant-supported zirconia prostheses: A systematic review. Eur J Oral Implantol 2017;10 Suppl 1:35-45.

49. Pozzi A, Arcuri L, Fabbri G, Singer G, Londono J. Long-term survival and success of zirconia screw-retained implant-supported prostheses for up to 12 years: A retrospective multicenter study. J Prosthet Dent 2023;129(1):96-108.

50. Park CJ, Phark JH, Chee WW. Evaluation of Fracture Resistance of Varying Thicknesses of Zirconia Around Implant Abutment Cylinders. J Oral Implantol 2017;43(5):328-32.

51. Kim JW, Park E, Golestanian V. Fracture Resistance of Screw-Access Holes in Zirconia Full-Arch Implants. Int J Prosthodont 2022;35(4):480-86.

52. Tirone F, Salzano S, Rolando E, Pozzatti L, Rodi D. Framework Fracture of Zirconia Supported Full Arch Implant Rehabilitation: A Retrospective Evaluation of Cantilever Length and Distal Cross-Sectional Connection Area in 140 Patients Over an Up-To-7 Year Follow-Up Period. J Prosthodont 2022;31(2):121-29.

53. Rojas Vizcaya F. Retrospective 2- to 7-Year Follow-Up Study of 20 Double Full-Arch Implant-Supported Monolithic Zirconia Fixed Prostheses: Measurements and Recommendations for Optimal Design. J Prosthodont 2018;27(6):501-08.

54. Papaspyridakos P, Sinada N, Ntovas P, Barmak AB, Chochlidakis K. Zirconia full-arch implant prostheses: Survival, complications, and prosthetic space dimensions with 115 edentulous jaws. J Prosthodont 2024.

55. Gonzalez J, Triplett RG. Complications and Clinical Considerations of the Implant-Retained Zirconia Complete-Arch Prosthesis with Various Opposing Dentitions. Int J Oral Maxillofac Implants 2017;32(4):864-69.

56. Saponaro PC, Karasan D, Donmez MB, Johnston WM, Yilmaz B. Prosthetic complications with monolithic or micro-veneered implant-supported zirconia single-unit, multiple-unit, and complete-arch prostheses on titanium base abutments: A single center retrospective study with mean follow-up period of 72.35 months. Clin Implant Dent Relat Res 2023;25(1):99-106.

57. Venezia P, Torsello F, Cavalcanti R, D'Amato S. Retrospective analysis of 26 complete-arch implant-supported monolithic zirconia prostheses with feldspathic porcelain veneering limited to the facial surface. J Prosthet Dent 2015;114(4):506-12.

58. Eckert SE, Hueler G, Sandler N, Elkattah R, McNeil DC. Immediately Loaded Fixed Full-Arch Implant-Retained Prosthesis: Clinical Analysis When Using a Moderate Insertion Torque. Int J Oral Maxillofac Implants 2019;34(3):737-44.

59. Beresford D, Klineberg I. A Within-Subject Comparison of Patient Satisfaction and Quality of Life Between a Two-Implant Overdenture and a Three-Implant-Supported Fixed Dental Prosthesis in the Mandible. Int J Oral Maxillofac Implants 2018;33(6):1374-82.

60. Vazouras K, Taylor T. Full-Arch Removable vs Fixed Implant Restorations: A Literature Review of Factors to Consider Regarding Treatment Choice and Decision-Making in Elderly Patients. Int J Prosthodont 2021;34:s93-s101.

61. Allen F, Locker D. A modified short version of the oral health impact profile for assessing health-related quality of life in edentulous adults. Int J Prosthodont 2002;15(5):446-50.

62. Yao CJ, Cao C, Bornstein MM, Mattheos N. Patient-reported outcome measures of edentulous patients restored with implant-supported removable and fixed prostheses: A systematic review. Clin Oral Implants Res 2018;29 Suppl 16:241-54.

63. De Kok IJ, Chang KH, Lu TS, Cooper LF. Comparison of three-implant-supported fixed dentures and two-implant-retained overdentures in the edentulous mandible: a pilot study of treatment efficacy and patient satisfaction. Int J Oral Maxillofac Implants 2011;26(2):415-26.

64. de Souza FI, de Souza Costa A, Dos Santos Pereira R, et al. Assessment of Satisfaction Level of Edentulous Patients Rehabilitated with Implant-Supported Prostheses. Int J Oral Maxillofac Implants 2016;31(4):884-90.

65. Martin-Ares M, Barona-Dorado C, Guisado-Moya B, et al. Prosthetic hygiene and functional efficacy in completely edentulous patients: satisfaction and quality of life during a 5-year follow-up. Clin Oral Implants Res 2016;27(12):1500-05.

66. Martinez-Gonzalez JM, Martin-Ares M, Cortes-Breton Brinkmann J, Calvo-Guirado JL, Barona-Dorado C. Impact of prosthetic rehabilitation type on satisfaction of completely edentulous patients. A 5-year prospective study. Acta Odontol Scand 2013;71(5):1303-8.

67. Oh SH, Kim Y, Park JY, et al. Comparison of fixed implant-supported prostheses, removable implant-supported prostheses, and complete dentures: patient satisfaction and oral health-related quality of life. Clin Oral Implants Res 2016;27(2):e31-7.

68. Quirynen M, Alsaadi G, Pauwels M, et al. Microbiological and clinical outcomes and patient satisfaction for two treatment options in the edentulous lower jaw after 10 years of function. Clin Oral Implants Res 2005;16(3):277-87.

69. Lambert FE, Weber HP, Susarla SM, Belser UC, Gallucci GO. Descriptive analysis of implant and prosthodontic survival rates with fixed implant-supported rehabilitations in the edentulous maxilla. J Periodontol 2009;80(8):1220-30.

70. Killip S, Mahfoud Z, Pearce K. What is an intracluster correlation coefficient? Crucial concepts for primary care researchers. Ann Fam Med 2004;2(3):204-8.

71. White IR, Daniel R, Royston P. Avoiding bias due to perfect prediction in multiple imputation of incomplete categorical variables. Comput Stat Data Anal 2010;54(10):2267-75.

72. Sailer I, Strasding M, Valente NA, et al. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses. Clin Oral Implants Res 2018;29 Suppl 16:184-98.

73. Wittneben JG, Buser D, Salvi GE, et al. Complication and failure rates with implant-supported fixed dental prostheses and single crowns: a 10-year retrospective study. Clin Implant Dent Relat Res 2014;16(3):356-64.

74. Carames J, Tovar Suinaga L, Yu YC, Perez A, Kang M. Clinical Advantages and Limitations of Monolithic Zirconia Restorations Full Arch Implant Supported Reconstruction: Case Series. Int J Dent 2015;2015:392496.

75. Limmer B, Sanders AE, Reside G, Cooper LF. Complications and patient-centered outcomes with an implant-supported monolithic zirconia fixed dental prosthesis: 1 year results. J Prosthodont 2014;23(4):267-75.

76. Chochlidakis K, Ercoli C, Einarsdottir E, et al. Implant survival and biologic complications of implant fixed complete dental prostheses: An up to 5-year retrospective study. J Prosthet Dent 2022;128(3):375-81.

77. Drago C. Cantilever Lengths and Anterior-Posterior Spreads of Interim, Acrylic Resin, Full-Arch Screw-Retained Prostheses and Their Relationship to Prosthetic Complications. J Prosthodont 2017;26(6):502-07.

Appendices:

Appendix A:

Table 1: Subject Timeline

Appointment / Procedures	Visit 1
Informed Consent Form	X
Demographics & Medical History	X
Evaluate eligibility and withdrawal criteria	X
Oral Examination	X
Periodontal and Prosthodontic Examination	X
Radiographic Examination, if needed	X
Complication Assessment	X
Questionnaire	X
Gift cards & Transportation	X

Table 2: Demographics

	Mean	SD	Min	Max
Age (Years)	66.98	12.1	32	83

Variable		Sample Size (44)	Percentage
Gender	Female	20	45.5%
	Male	24	54.5%
Race	White	41	93.2%
	Black	1	2.3%
	Asian	2	4.5%
Ethnicity	Hispanic	4	9.1%
	Non-Hispanic	39	88.6%
	African American	1	2.3%

Table 3: Lifestyle and Medical History

Variable		Sample Size (44)	Percentage
Smoking	No	39	88.6%
	Yes	5	11.4%
Diabetes	No	41	93.2%
	Yes	3	6.8%
Jaw irradiation	No	44	100%
Cancer	No	43	97.7%
	Yes	1	2.3%
Bisphosphonates	No	43	97.7%
	Yes	1	2.3%

Table 4: Prostheses Related Factors:

Variable	Category	Sample size (44)	Percent (%)
Nightguard use	No	32	72.7%
	Yes	12	27.3%
Bruxism	No	33	75.0%
	Yes	11	25.0%
Opposing dentition	Natural dentition	8	13.1%
	Implant supported	31	50.8%
	Removable prosthesis	9	14.8%
	Mixed (Teeth and implant)	12	19.7%
	Implant overdenture	1	1.6%
Cantilever	No	41	67.2%
	Yes	20	32.8%
Jaw	Maxilla	32	52.5%
	Mandible	29	47.5%
Abutment level prosthesis or implant level prosthesis	Abutment level	60	98.4%
	Implant level	1	1.6%
Number of teeth	10	1	1.6%
	12	58	95.1%
	13	1	1.6%
	14	1	1.6%
Number of abutments	4	4	6.6%
	5	4	6.6%
	6	52	85.2%
	7	1	1.6%
Number of implants	4	4	6.6%
	5	4	6.6%
	6	52	85.2%
	7	1	1.6%

	Mean	SD	Min	Max
Months with prosthesis	28.67	18.32	12	71

Table 5: Minor Technical Complications

Minor technical complications		Sample Size (61)	Percent
Occlusal Wear	No	55	90.2%
	Yes	6	9.8%
Loss of Access Hole Material	No	53	86.9%
	Yes	8	13.1%
Loosening of Abutment	No	61	100%
Chipping	No	54	88.5%
	Yes	7	11.5%
Fracture of Veneer	No	60	98.4
	Yes	1	1.6%
Screw Loosening	No	58	95.1%
	Yes	3	4.9%
Wear of Prosthetic Screw	No	54	88.5%
	Yes	7	11.5%
Ti-base Decementation	No	53	86.9%
	Yes	8	13.1%

Table 6: Major technical complications

Major technical complications		Sample Size (20)	Percent
Fracture of an abutment	No	61	100%
Fracture of framework	No	59	96.7%
	Yes	2	3.3%
Fracture of implant	No	61	100%
Fracture of screw	No	60	98.4%
	Yes	1	1.6%

Table 7: Descriptive Statistics About Complication Events

	Mean	SD	Median (25th and 75th Percentile)
Number of minor complication events	0.74	1.12	0 (0-1)
Number of major complication events	0.07	0.250	0 (0-0)
Total number of complication events	0.8	1.15	0 (0-1.5)

Table 8: Bivariate Analysis of Wear of Material

Independent Variable (Categorical)	Category	Wear of Material	Percent	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Gender	Female	No=26	96.3%	0.27	0.03	2.64	0.260
		Yes=1	3.7%				
	Male^	No=29	85.3%				
		Yes=5	14.7%				
Smoking	Non-Smoker	No=47	47%	0.15	0.004	4.76	0.279
		Yes=6	6%				
	Smoker^	No=8	100%				
		Yes=0	0%				
Jaw	Maxillary	No=27	84.4%	2.69	0.72	10.01	0.140
		Yes=5	15.6%				
	Mandible^	No=28	96.6%				
		Yes=1	3.4%				
Nightguard use	No Use	No=38	88.4%	1.61	0.20	13.09	0.655
		Yes=5	11.6%				
	Use^	No=17	94.4%				
		Yes=1	5.6%				
Bruxism	Does not have	No=41	91.1%	0.64	0.09	4.41	0.654
		Yes=4	8.9%				
	Have^	No=14	87.5%				
		Yes=2	12.5%				

^ reference category

Independent Variable (Continuous)	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	0.96	1.07	0.528
Age (Years)	0.96	0.89	1.02	0.207
Number of teeth	0.97	0.60	1.58	0.917
Number of implants	2.99	1.08	8.22	0.034

Table 9: Bivariate Analysis of Loss of Access Material

Independent Variable (Categorical)	Category	Loss of Access Material	Percent	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Gender	Female	No=23	85.2%	1.01	0.18	5.75	0.987
		Yes=4	14.8%				
	Male^	No=30	88.2%				
		Yes=4	11.8%				
Smoking	Non-Smoker	No=46	86.8%	0.52	0.05	5.71	0.595
		Yes=7	13.2%				
	Smoker^	No=7	87.5%				
		Yes=1	12.5%				
Jaw	Maxillary	No=29	90.6%	0.60	0.22	1.63	0.314
		Yes=3	9.4%				
	Mandible^	No=24	82.8%				
		Yes=5	17.2%				
Nightguard use	No Use	No=37	86%	1.26	0.75	2.12	0.386
		Yes=6	14%				
	Use^	No=16	88.9%				
		Yes=2	11.1%				
Bruxism	Does not have	No=38	84.4%	1.67	0.17	16.13	0.659
		Yes=7	15.6%				
	Have^	No=15	93.8%				
		Yes=1	6.3%				

^ reference category

Independent Variable (Continuous)	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.01	0.96	1.06	0.607
Age (Years)	1.15	0.97	1.36	0.119
Number of teeth	1.00	0.85	1.18	0.982
Number of implants	16.80	0.56	499.65	0.103

Table 10: Bivariate Analysis of Chipping

Independent Variable (Categorical)	Category	Chipping	Percent	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Gender	Female	No=26	96.3%	0.20	0.02	1.61	0.130
		Yes=1	3.7%				
	Male^	No=28	82.4%				
		Yes=6	11.5%				
Smoking	Non-Smoker	No=46	86.8%	0.08	0.003	1.81	0.114
		Yes=7	13.2%				
	Smoker^	No=8	100%				
		Yes=0	0%				
Jaw	Maxillary	No=26	81.3%	6.16	0.80	47.61	0.082
		Yes=6	18.8%				
	Mandible^	No=28	96.6%				
		Yes=1	3.4%				
Nightguard use	No Use	No=40	93%	0.33	0.07	1.55	0.159
		Yes=3	7%				
	Use^	No=14	77.8%				
		Yes=4	22.2%				
Bruxism	Does not have	No=40	88.9%	0.98	0.18	5.23	0.977
		Yes=5	11.1%				
	Have^	No=14	87.5%				
		Yes=2	12.5%				

^ reference category

Independent Variable (Continuous)	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.05	1.01	1.09	0.009
Age (Years)	1.09	0.98	1.21	0.106
Number of teeth	0.83	0.36	1.91	0.660
Number of implants	3.04	1.09	8.51	0.034

Table 11: Bivariate Analysis of Wear of Prosthetic Screw

Independent Variable (Categorical)	Category	Wear of Prosthetic Screw	Percent	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Gender	Female	No=23	85.2%	2.14	0.30	15.06	0.444
		Yes=4	14.8%				
	Male^	No=31	91.2%				
		Yes=3	8.8%				
Smoking	Non-Smoker	No=46	86.8%	0.17	0.004	6.43	0.338
		Yes=7	13.2%				
	Smoker^	No=8	100%				
		Yes=0	0%				
Jaw	Maxillary	No=29	90.6%	0.99	0.14	7.19	1.000
		Yes=3	9.4%				
	Mandible^	No=25	86.2%				
		Yes=4	13.8%				
Nightguard use	No Use	No=38	88.4%	0.99	0.99	1.00	0.461
		Yes=5	11.6%				
	Use^	No=16	88.9%				
		Yes=2	11.1%				
Bruxism	Does not have	No=39	86.7%	1.0001	0.10	10.16	1.000
		Yes=6	13.3%				
	Have^	No=15	93.8%				
		Yes=1	6.3%				

^ reference category

Independent Variable (Continuous)	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.03	0.97	1.09	0.313
Age (Years)	1.02	0.95	1.10	0.597
Number of teeth	0.93	0.17	5.13	0.938
Number of implants	2.95	1.09	8.00	0.034

Table 12: Bivariate Analysis of Debonding of Ti-Base

Independent Variable (Categorical)	Category	Debonding of Ti-Base	Percent	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Gender	Female	No=20	74.1%	12.66	1.45	110.90	0.022
		Yes=7	25.9%				
	Male^	No=33	97.1%				
		Yes=1	2.9%				
Smoking	Non-Smoker	No=45	84.9%	0.11	0.01	2.42	0.163
		Yes=8	15.1%				
	Smoker^	No=8	100%				
		Yes=0	0%				
Jaw	Maxillary	No=28	87.5%	0.92	0.28	3.08	0.895
		Yes=4	12.5%				
	Mandible^	No=25	86.2%				
		Yes=4	13.8%				
Nightguard use	No Use	No=37	86%	0.97	0.18	5.29	0.971
		Yes=6	14%				
	Use^	No=16	88.9%				
		Yes=2	11.1%				
Bruxism	Does not have	No=39	86.7%	1.04	0.18	6.04	0.968
		Yes=6	13.3%				
	Have^	No=14	87.5%				
		Yes=2	12.5%				

^ reference category

Independent Variable (Continuous)	Odds ratio	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.03	0.99	1.08	0.137
Age (Years)	0.97	0.91	1.02	0.246
Number of teeth	4.02	1.75	9.25	0.001
Number of implants	0.80	0.23	2.81	0.729

Table 13: Bivariate Analysis of Minor Complications Events

Independent Variable (Categorical)	Category	Mean (SD)	Median (25^{th}-75^{th} Percentile)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Gender	Female	0.85 (1.19)	0 (0-1)	1.30	0.59	2.87	0.511
	Male^	0.65 (1.07)	0 (0-1.25)				
Smoking	Non-Smoker	0.83 (1.17)	0 (0-2)	5.93	0.86	41.10	0.072
	Smoker^	0.13 (0.35)	0 (0-0)				
Jaw	Maxillary	0.75 (1.04)	0 (0-1)	1.03	0.49	2.18	0.936
	Mandible^	0.72 (1.22)	0 (0-1.5)				
Nightguard use	No Use	0.77 (1.21)	0 (0-2)	1.03	0.46	2.33	0.936
	Use^	0.67 (0.9)	0 (0-1)				
Bruxism	Does not have	0.76 (1.15)	0 (0-1.5)	0.97	0.40	2.36	0.951
	Have^	0.69 (1.07)	0 (0-1)				

^ reference category

Independent Variable (Continuous)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	1.00	1.04	0.047
Age (Years)	1.01	0.98	1.04	0.581
Number of teeth	1.44	1.05	1.98	0.024
Number of implants	2.20	1.10	4.40	0.026

Table 14: Bivariate Analysis of Minor Complications

Independent Variable (Categorical)	Category	Mean (SD)	Median (25^{th}-75^{th} Percentile)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Gender	Female	0.7 (0.82)	0 (0-1)	1.20	0.55	2.61	0.648
	Male^	0.59 (0.98)	0 (0-1)				
Smoking	Non-Smoker	0.72 (0.94)	0 (0-1.5)	4.11	0.63	26.66	0.138
	Smoker^	0.13 (0.35)	0 (0-0)				
Jaw	Maxillary	0.69 (0.96)	0 (0-1)	1.19	0.63	2.25	0.601
	Mandible^	0.59 (0.86)	0 (0-1.5)				
Nightguard use	No Use	0.65 (0.97)	0 (0-1)	0.79	0.37	1.68	0.533
	Use^	0.61 (0.77)	0 (0-1)				
Bruxism	Does not have	0.67 (0.95)	0 (0-1)	0.95	0.42	2.14	0.905
	Have^	0.56 (0.81)	0 (0-1)				

^ reference category

Independent Variable (Continuous)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	1.00	1.04	0.073
Age (Years)	1.01	0.97	1.05	0.716
Number of teeth	1.28	0.97	1.69	0.077
Number of implants	2.14	1.02	4.51	0.045

Table 15: Bivariate Analysis of Total Complications Events

Independent Variable (Categorical)	Category	Mean (SD)	Median (25^{th}-75^{th} Percentile)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Gender	Female	0.93 (1.2)	1 (0-2)	1.31	0.63	2.73	0.470
	Male^	0.71 (1.11)	0 (0-1.25)				
Smoking	Non-Smoker	0.89 (1.18)	0 (0-2)	3.38	0.48	23.72	0.221
	Smoker^	0.25 (0.7)	0 (0-0)				
Jaw	Maxillary	0.81 (1.09)	0 (0-1)	1.03	0.51	2.10	0.935
	Mandible^	0.79 (1.23)	0 (0-2)				
Nightguard use	No Use	0.84 (1.25)	0 (0-2)	1.11	0.53	2.33	0.781
	Use^	0.72 (0.89)	0.50 (0-1)				
Bruxism	Does not have	0.82 (1.19)	0 (0-2)	1.02	0.46	2.28	0.952
	Have^	0.75 (1.06)	0 (0-1)				

^ reference category

Independent Variable (Continuous)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	1.003	1.04	0.019
Age (Years)	1.02	0.98	1.05	0.332
Number of teeth	1.44	1.05	1.99	0.025
Number of implants	2.65	1.33	5.26	0.005

Table 16: Bivariate Analysis of Total Complications

Independent Variable (Categorical)	Category	Mean (SD)	Median (25^{th}-75^{th} Percentile)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Gender	Female	0.78 (0.84)	1 (0-2)	1.22	0.59	2.52	0.584
	Male^	0.65 (1.01)	0 (01.25)				
Smoking	Non-Smoker	0.77 (0.95)	0 (0-2)	2.35	0.36	15.48	0.374
	Smoker^	0.25 (0.7)	0 (0-0)				
Jaw	Maxillary	0.75 (0.98)	0 (0-1)	1.19	0.65	2.19	0.567
	Mandible^	0.66 (0.89)	0 (0-2)				
Nightguard use	No Use	0.72 (1)	0 (0-2)	0.98	0.50	1.93	0.948
	Use^	0.67 (0.76)	0.5 (0-1)				
Bruxism	Does not have	0.73 (0.98)	0 (0-2)	1.01	0.48	2.09	0.988
	Have^	0.63 (0.8)	0 (0-1)				

^ reference category

Independent Variable (Continuous)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	1.002	1.04	0.033
Age (Years)	1.02	0.98	1.06	0.432
Number of teeth	1.33	0.99	1.78	0.057
Number of implants	2.65	1.22	5.76	0.014

Table 17: Multivariable Analysis of Minor Complications Events

Independent Variable (Categorical)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Gender	1.69	0.72	3.98	0.226
Smoking	3.28	0.70	15.34	0.132
Jaw	1.28	0.68	2.43	0.448
Nightguard use	1.03	0.49	2.17	0.946
Bruxism	0.95	0.46	1.97	0.891

Independent Variable (Continuous)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	1.002	1.03	0.033
Age (Years)	1.01	0.98	1.03	0.592

Table 18: Multivariable Analysis of Minor Complications

Independent Variable (Categorical)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Gender	2.38	1.02	5.55	0.045
Smoking	0.16	0.05	0.57	0.004
Jaw	1.71	1.17	2.50	0.006
Nightguard use	0.81	0.50	1.31	0.391
Bruxism	0.55	0.26	1.17	0.123

Independent Variable (Continuous)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	1.004	1.04	0.017
Age (Years)	1.001	0.97	1.03	0.933

Table 19: Multivariable Analysis of Total Complications Events

Independent Variable (Categorical)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Gender	1.84	0.82	4.12	0.141
Smoking	2.11	0.45	9.91	0.343
Jaw	1.12	0.58	2.15	0.742
Nightguard use	1.10	0.54	2.24	0.784
Bruxism	1.07	0.57	1.99	0.833

Independent Variable (Continuous)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	1.01	1.04	0.004
Age (Years)	1.02	0.99	1.04	0.184

Table 20: Multivariable Analysis of Total Complications

Independent Variable (Categorical)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Gender	1.69	0.7712	3.69	0.190
Smoking	1.20	0.28	5.14	0.805
Jaw	1.65	0.97	2.83	0.067
Nightguard use	1.01	0.51	2.00	0.969
Bruxism	1.00	0.53	1.89	0.998

Independent Variable (Continuous)	Exponentiated Coefficient	95% CI Lower	95% CI Upper	P-Value
Follow-up Time (Months)	1.02	1.001	1.03	0.042
Age (Years	1.01	0.99	1.04	0.260

TABLE 21: Surface area (mm²) for maxillary and mandibular zirconia IFCDPs.

	Maxilla (n = 32 jaws/189 implants)				Mandible (n = 29 jaws/166 implants)			
Cross-section	**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**	**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**
Posterior surface area								
Lingual side of abutment	26.53 (12.95)	23.54 (17.41-33.12)	5.05	74.67	27.19 (14.31)	23.47 (15.82-35.1)	9.99	75.18
Buccal side of abutment	46.15 (21.63)	39.92 (31.38-56.04)	16.13	109.77	42.66 (20.25)	36.27 (29.25-53.07)	6.91	117.35
Connector	79.73 (23.88)	76 (58.12-94.56)	27.68	142.12	83.54 (23.13)	85.33 (66.39-98.97)	21.68	137.63
Pontic	100.42 (25.49)	98.15 (79.04-114.73)	53.18	169.37	109.38 (20.97)	106.81 (98.18-122.7)	53.23	160.83
Anterior surface area								
Lingual side of abutment	14.47 (6.2)	13.39 (9.63-17.57)	5.91	33.09	17.02 (7.59)	15.85 (9.93-23.14)	6.48	36.01
Buccal side of abutment	55.32 (17.47)	53.5 (40.3-69.18)	25.54	99.80	57.7 (16.05)	58.06 (45.8-69.91)	20.28	90.54
Connector	76.76 (21.71)	75.33 (61.25-93.24)	27.08	142.12	86.7 (22.12)	87.08 (68.77-104.48)	33.11	131.91
Pontic	96.04 (21.29)	95.63 (80.54-110.02)	56.04	166.10	100.72 (22.21)	98.67 (85.05-117.31)	56.13	156.78

Note: Measurements in mm².

TABLE 22: Linear measurements (in mm) for maxillary and mandibular zirconia prostheses.

	Maxilla (n = 32 jaws/189 implants)					Mandible (n = 29 jaws/166 implants)			
Posterior	**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**		**Mean (SD**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**
Lingual side of abutment (Height)	10.13 (2.4)	9.85 (8.38-11.76)	5.22	16.84		10.61 (2.33)	10.33 (8.85-11.73)	6	19.47
Lingual side of abutment (Width)	3.42 (1.16)	3.37 (2.5-4.09)	0.90	6.98		3.35 (1.29)	3.12 (2.46-3.97)	1.38	10.38
Buccal side of abutment (Height)	11.62 (2.11)	11.35 (10.12-13.1)	5.96	17.81		11.92 (2.21)	12.03 (10.38-13.26)	4.96	16.85
Buccal side of abutment (Width)	4.57 (1.63)	4.29 (3.5-5.38)	1.18	10.26		4.4 (1.72)	4.08 (3.15-5.35)	0.67	9.37
Connector (Height)	10.12 (2.09)	10.28 (8.68-11.55)	4.30	16.38		11.81 (2.5)	11.75 (10.39-13.4)	3.19	18.29
Connector (Width)	9.64 (1.63)	9.57 (8.4-10.58)	6.07	13.91		9.49 (1.66)	9.44 (8.18-10.48)	6	13.16
Pontic (Height)	10.25 (2.39)	10.33 (8.56-11.62)	5.19	16.64		13.56 (2.29)	13.73 (12.03-15.4)	5.60	18.47
Pontic (Width)	10.46 (1.02)	10.4 (9.75-11.15)	7.89	13.24		9.78 (1.2)	9.67 (9.01-10.63)	7.27	12.81
Anterior	**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**		**Mean (SD**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**
Lingual side of abutment (Height)	7.85 (1.82)	7.7 (6.31-8.78)	4.47	12.78		8.17 (2.45)	7.9 (7.07-9.78)	1.75	13.86
Lingual side of abutment (Width)	2.50 (0.98)	2.31 (1.78-3.06)	1.22	6.97		3 (1.29)	2.67 (2.1-3.51)	1.18	6.70
Buccal side of abutment (Height)	13.46 (2.18)	13.25 (12.01-15.1)	7.34	18.93		14.65 (2.58)	14.85 (13.17-16.25)	6.02	19.20
Buccal side of abutment (Width)	5.53 (1.62)	5.5 (4.15-6.6)	2.55	10.48		5.35 (1.68)	5.28 (4.13-6.27)	2.43	9.39
Connector (Height)	11.86 (2.34)	12.05 (10.5-13.46)	5.59	19.22		14.25 (2.77)	14.17 (12.75-15.92)	4.83	20.07
Connector (Width)	9.56 (1.75)	9.72 (8.1-10.98)	5.75	12.76		9.72 (2.01)	9.58 (8.6-11.04)	4.34	13.68
Pontic (Height)	13.97 (1.55)	13.77 (13.03-14.82)	9.25	18.37		15.49 (2.46)	15.88 (14.12-17.22)	9.64	20.67
Pontic (Width)	10.33 (1.69)	10.78 (9.08-11.52)	6.45	15.77		9.68 (1.65)	9.5 (8.64-10.71)	5.55	13.36

TABLE 23: Surface area (mm²) for two fractured zirconia prostheses IFCDPs.

	Maxilla (n = 1 jaw/6 implants)				Mandible (n = 1 jaw/7 implants)			
	Mean (SD)	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**	**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**
Posterior surface area								
Lingual side of abutment	28.05 (13.42)	28.22 (14.99-40.94)	12.04	43.72	19.98 (13.1)	12.32 (11.26-32.53)	10.39	41.47
Buccal side of abutment	34.36 (7.56)	33.78 (27.68-41.61)	27.45	42.43	37.34 (6.36)	34.95 (31.82-44.07)	31.21	45.50
Connector	68.99 (6.93)	69.51 (63.6-74.04)	58.85	78.40	32.79 (9.26)	34.97 (21.99-39.6)	21.68	45.36
Pontic	87.94 (12.49)	84.18 (77.77-84.18)	77.77	101.89	78.73		78.73	78.73
Anterior surface area								
Lingual side of abutment	6.59 (0.96)	6.59 (5.91-6.59)	5.91	7.28	9.14 (1.09)	9.14 (8.37-9.14)	8.37	9.92
Buccal side of abutment	48.69 (5.27)	48.69 (44.96-48.69)	44.96	52.42	30.39 (14.29)	30.39 (20.28-30.39)	20.28	40.50
Connector	69.76 (7.65)	68.7 (62.7-68.7)	62.70	77.89	41.08 (5.86)	42.03 (35.17-46.03)	33.11	47.15
Pontic	93.2 (5.96)	92.99 (86.83-99.62)	86.54	100.43	67 (9.07)	66.28 (58.78-75.58)	56.13	79.6

Note: Measurements in mm².

TABLE 24: Linear measurements (in mm) for the two fractured zirconia prostheses.

	Maxilla (n = 1 jaw/6 implants)					Mandible (n = 1 jaw/7 implants)			
Posterior	**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**		**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**
Lingual side of abutment (Height)	9.26 (1.62)	9.85 (7.61-10.33)	6.87	10.49		9.10 (1.57)	9.26 (7.69-10.43)	6.98	11.26
Lingual side of abutment (Width)	3.76 (1.29)	3.55 (2.66-5.07)	2.43	25.52		2.58 (0.96)	2.77 (1.67-3.4)	1.60	3.97
Buccal side of abutment (Height)	10.39 (1.23)	10.8 (9.09-11.27)	8.60	11.35		10.26 (1.19)	9.72 (9.31-11.48)	9.02	11.95
Buccal side of abutment (Width)	4.16 (0.72)	4.14 (3.52-4.84)	3.50	4.89		4.96 (0.98)	5.18 (4.05-5.75)	3.64	6.30
Connector (Height)	9.1 (0.45)	9.04 (8.69-9.55)	8.68	9.76		6.14 (2.53)	5.7 (3.76-8.96)	3.19	9.52
Connector (Width)	8.84 (0.6)	8.94 (8.25-8.94)	8.07	9.61		6.96 (0.61)	7.09 (6.39-7.45)	6	7.72
Pontic (Height)	10.48 (1)	9.97 (9.85-9.97)	9.85	11.64		10.18		10.18	10.18
Pontic (Width)	10.44 (0.67)	10.42 (9.78-10.42)	9.78	11.13		8.95		8.95	8.95
Anterior	**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**		**Mean (SD)**	**Median (25^{th}-75^{th} Percentile)**	**Min**	**Max**
Lingual side of abutment (Height)	4.95 (0.26)	4.95 (4.77-4.95)	4.77	5.14		5.72 (0.16)	5.72 (5.6-5.72)	5.60	5.84
Lingual side of abutment (Width)	1.80 (0.29)	1.8 (1.59-1.8)	1.59	2.01		2.79 (0.5)	2.79 (2.44-2.79)	2.44	3.15
Buccal side of abutment (Height)	12.12 (0.44)	12.12 (11.81-12.12)	11.81	12.44		9.28 (3.57)	9.28 (6.75-9.28)	6.75	11.81
Buccal side of abutment (Width)	5.34 (1.43)	5.34 (4.33-5.34)	4.33	6.36		4.49 (1.29)	4.49 (3.58-4.49)	3.58	5.41
Connector (Height)	11.14 (1.36)	10.47 (10.25-10.47)	10.25	12.71		9.56 (3.54)	10.09 (5.95-12.64)	4.83	13.24
Connector (Width)	9.88 (0.93)	10.04 (8.88-10.04)	8.88	10.72		6.93 (0.68)	6.98 (6.25-7.56)	6.13	7.65
Pontic (Height)	13.46 (0.6)	13.46 (12.84-13.9)	12.48	14.07		13.33 (1.38)	14.26 (11.91-14.3)	11.23	14.32
Pontic (Width)	11.81 (0.79)	11.55 (11.16-12.61)	11.09	13		8.38 (1.69)	8.21 (6.77-10.09)	6.36	10.13

Table 25: Survey

Questionnaire OHIP-14						
Subject ID #:						
Dimension	**Questions**	**0 = never**	**1= hardly ever**	**2 = occasionally,**	**3 = fairly often**	**4 = very often**
Functional limitation	Have you had trouble pronouncing any words because of problems with your teeth, mouth or dentures?					
	Have you felt that your sense of taste has worsened because of problems with your teeth, mouth or dentures?					
Physical pain	Have you had painful aching in your mouth?					
	Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth or dentures?					
Psychological discomfort	Have you been self- conscious because of your teeth, mouth or dentures?					
	Have you felt tense because of problems with your teeth, mouth or dentures?					
Physical disability	Has your diet been unsatisfactory because of problems with your teeth, mouth or dentures?					
	Have you had to interrupt meals because of problems with your teeth, mouth or dentures?					
Psychological disability	Have you found it difficult to relax because of problems with your teeth, mouth or dentures?					
	Have you been a bit embarrassed because of problems with your teeth, mouth or dentures?					
Social disability	Have you been irritable with other people because of problems with your teeth, mouth or dentures?					
	Have you had difficulty doing your usual jobs because of problems with your teeth, mouth or dentures?					
Handicap	Have you felt that life in general was less satisfying because of problems with your teeth, mouth or dentures?					
	Have you been totally unable to function because of problems with your teeth, mouth or dentures?					
	Signature of the Investigator		**Signature of the patient**			**Date**

Table 26: Survey Answers

Category	Question	Answer	Sample size N	Percent (%)
Functional limitation	**1- Have you had trouble pronouncing any words because of problems with your teeth, mouth or dentures?**	Never	30	68.2
		Hardly ever	6	13.6
		Occasionally	6	13.6
		Fairly Often	2	4.5
	2- Have you felt that your sense of taste has worsened because of problems with your teeth, mouth or dentures?	Never	41	93.2
		Occasionally	3	6.8
Physical pain	**3- Have you had painful aching in your mouth?**	Never	33	75.0
		Hardly ever	5	11.4
		Occasionally	6	13.6
	4- Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth or dentures?	Never	31	70.5
		Hardly ever	6	13.6
		Occasionally	5	11.4
		Fairly Often	2	4.5
Psychological discomfort	**5- Have you been self- conscious because of your teeth, mouth or dentures?**	Never	35	79.5
		Hardly ever	2	4.5
		Occasionally	2	4.5
		Fairly Often	3	6.8
		Very often	2	4.5
	6- Have you felt tense because of problems with your teeth, mouth or dentures?	Never	34	77.3
		Hardly ever	3	6.8
		Occasionally	4	9.1
		Fairly Often	1	2.3
		Very often	2	4.5
Physical disability	**7- Has your diet been unsatisfactory because of problems with your teeth, mouth or dentures?**	Never	35	79.5
		Hardly ever	3	6.8
		Occasionally	5	11.4
		Fairly Often	1	2.3

Category	Question	Answer	Sample size N	Percent (%)
Physical disability	**8- Have you had to interrupt meals because of problems with your teeth, mouth or dentures?**	Never	35	79.5
		Hardly ever	5	11.4
		Occasionally	3	6.8
		Very often	1	2.3
Psychological disability	**9- Have you found it difficult to relax because of problems with your teeth, mouth or dentures?**	Never	38	86.4
		Hardly ever	3	6.8
		Occasionally	2	4.5
		Fairly Often	1	2.3
	10- Have you been a bit embarrassed because of problems with your teeth, mouth or dentures?	Never	35	79.5
		Hardly ever	1	2.3
		Occasionally	6	13.6
		Very often	2	4.5
Social disability	**11- Have you been irritable with other people because of problems with your teeth, mouth or dentures?**	Never	40	90.9
		Hardly ever	4	9.1
	12- Have you had difficulty doing your usual jobs because of problems with your teeth, mouth or dentures?	Never	40	90.9
		Hardly ever	4	9.1
Handicap	**13- Have you felt that life in general was less satisfying because of problems with your teeth, mouth or dentures?**	Never	36	81.8
		Hardly ever	2	4.5
		Occasionally	4	9.1
		Fairly often	1	2.3
		Very often	1	2.3
	14- Have you been totally unable to function because of problems with your teeth, mouth or dentures?	Never	41	93.2
		Hardly ever	1	2.3
		Occasionally	2	4.5

Appendix B:

Figure 1: Decementation of the ti-base

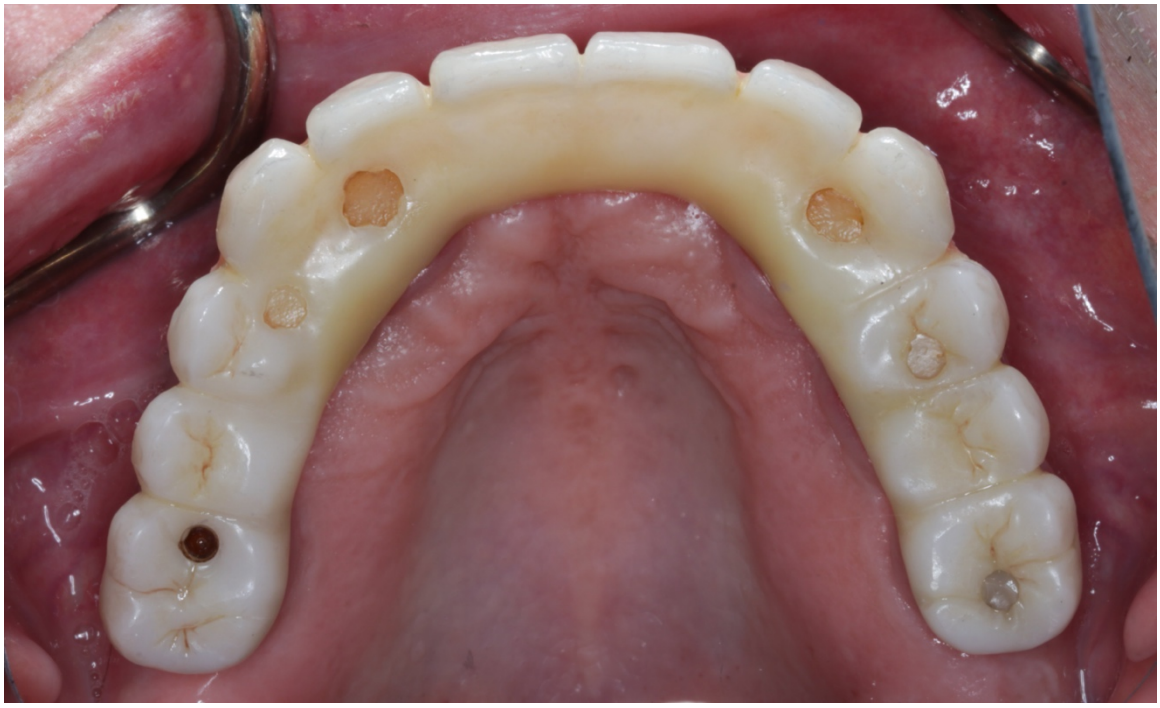

Figure 2: Loss of access hole material

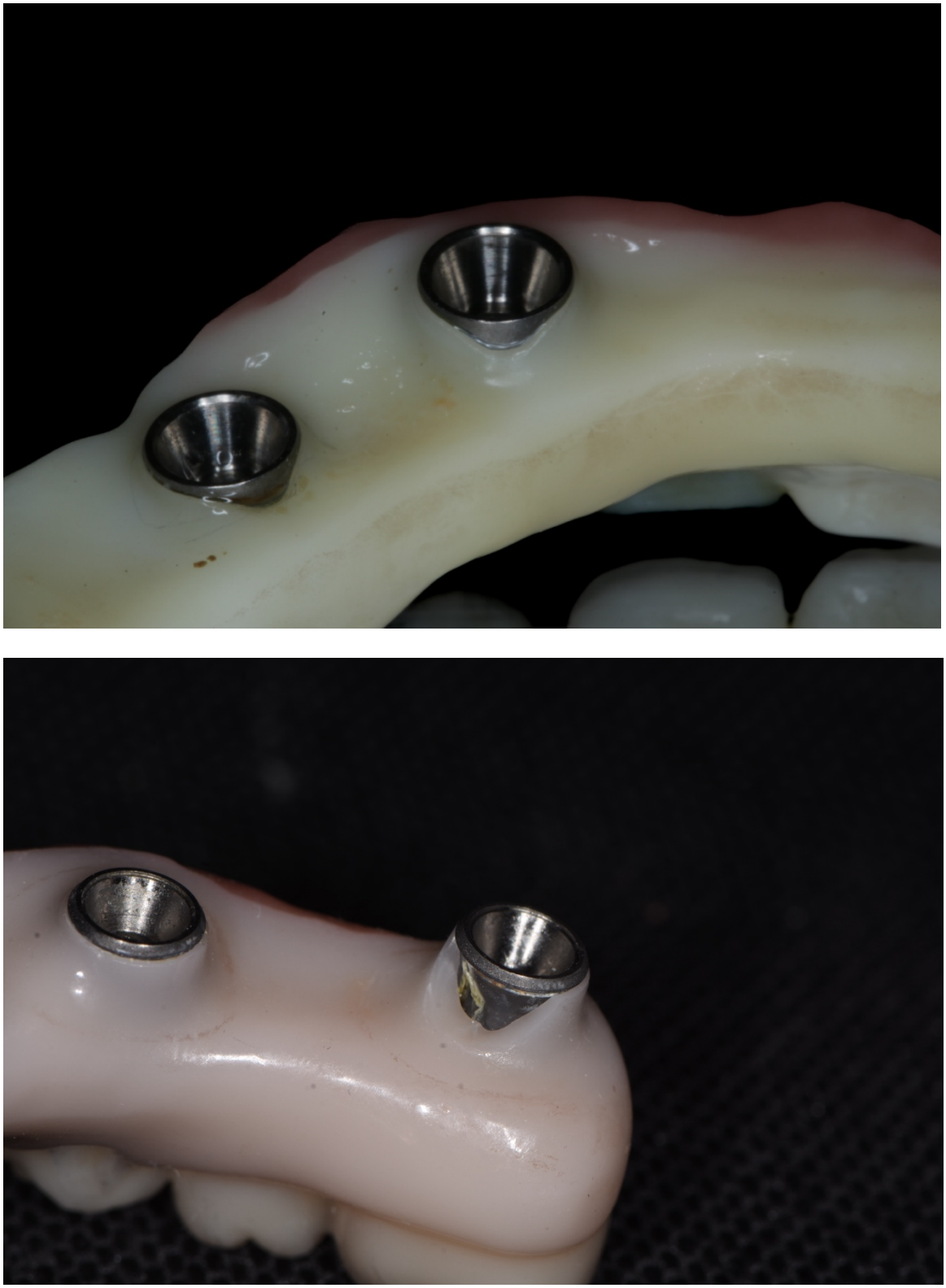

Figure 3: Chipping around the ti-bases

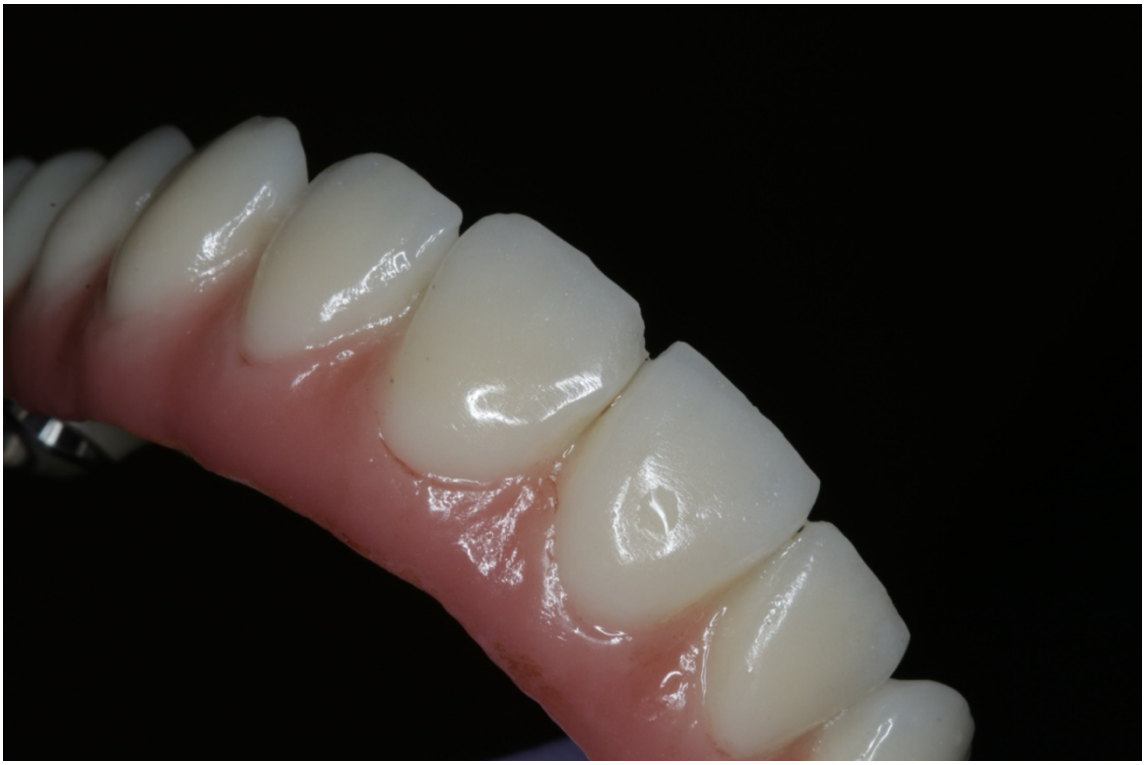

Figure 4: Fracture of the veneer material

Figure 5: Fracture of the prostheses

Measurements Figures:

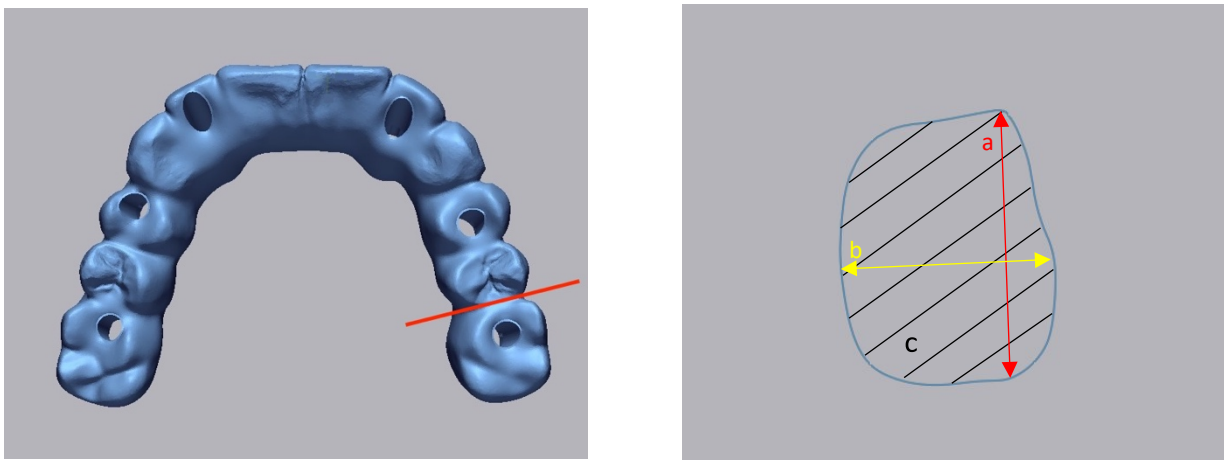

Figure 6. Maximum height recording in mm (a) maximum thickness recording (linear measurement) in mm (b) and surface area recording in mm^2 (c) in the site of each connector, based to the sectional plane with the minimum sectional area.

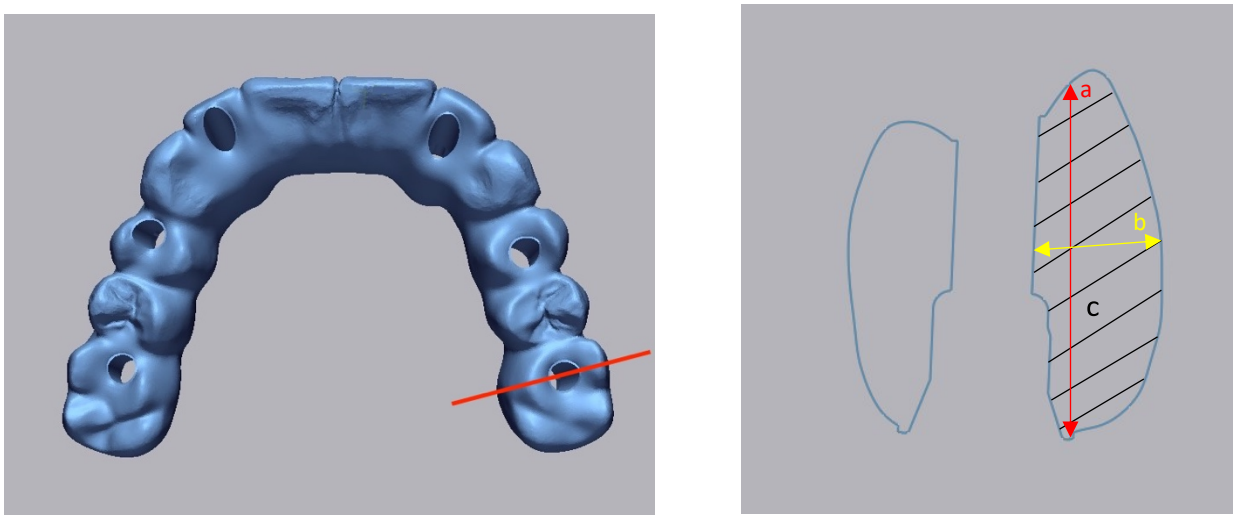

Figure 7. Maximum height recording in mm (a) maximum thickness recording (linear measurement) in mm (b) and surface area recording in mm^2 (c) for the buccal and the lingual section of each screw access opening, based to the sectional plane with the minimum sectional area.

Measurements Figures:

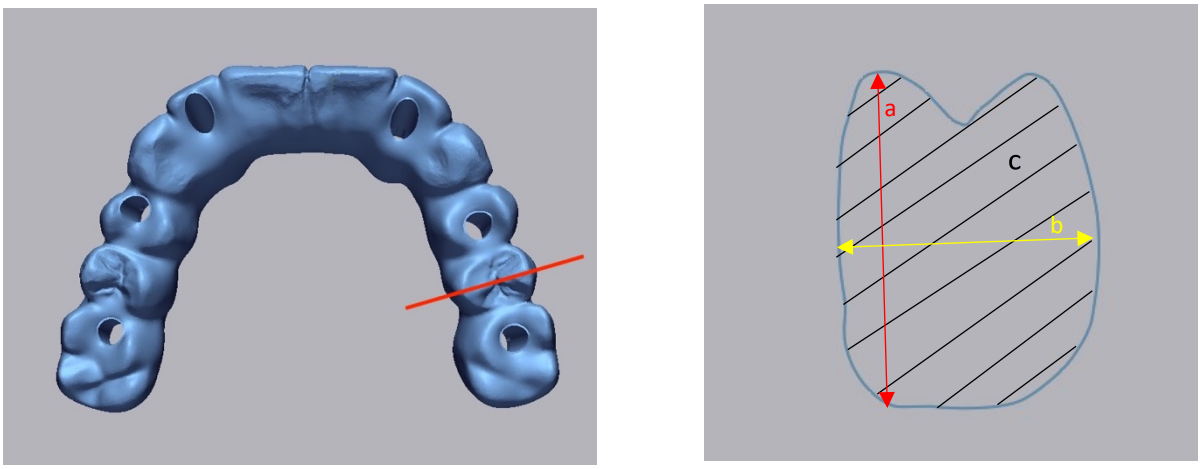

Figure 8. Maximum height recording in mm (a) maximum thickness recording (linear measurement) in mm (b) and surface area recording in mm^2 (c) in the site of each posterior space, based to the sectional plane with the minimum sectional area.

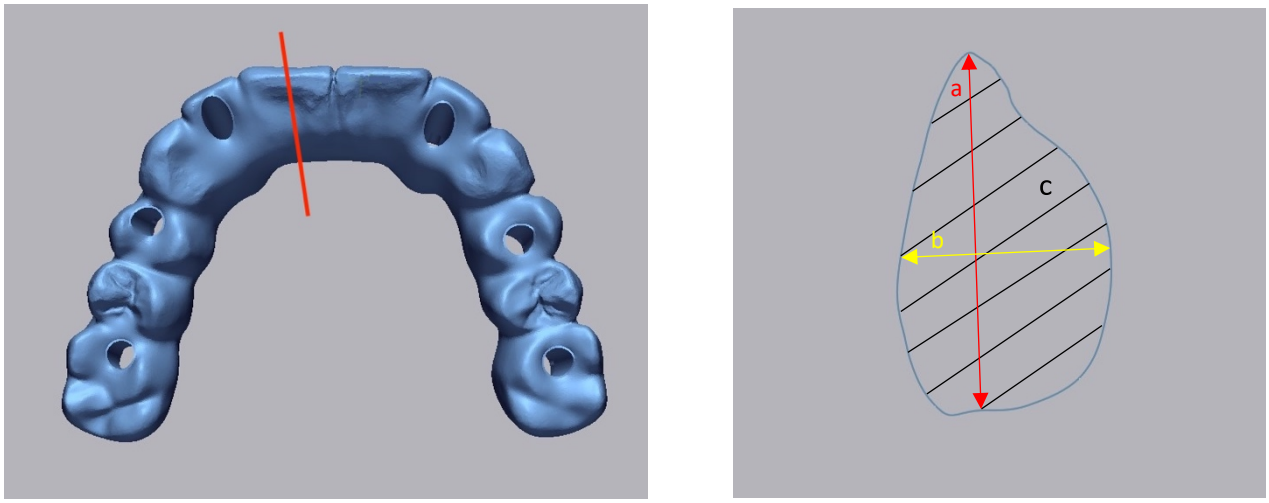

Figure 9. Maximum height recording in mm (a) maximum thickness recording (linear measurement) in mm (b) and surface area recording in mm^2 (c) in the site of each anterior space, based to the sectional plane with the minimum sectional area.

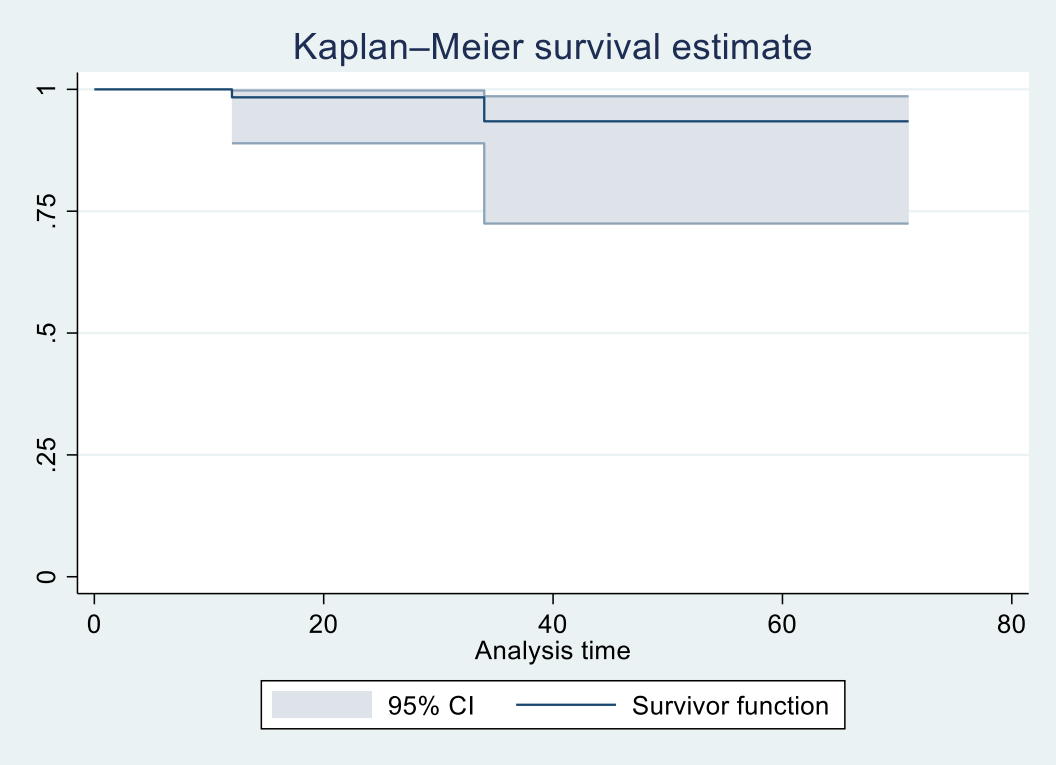

Figure 10. Kaplan-Meier curve for prosthesis fracture with a two-sided 95% confidence interval

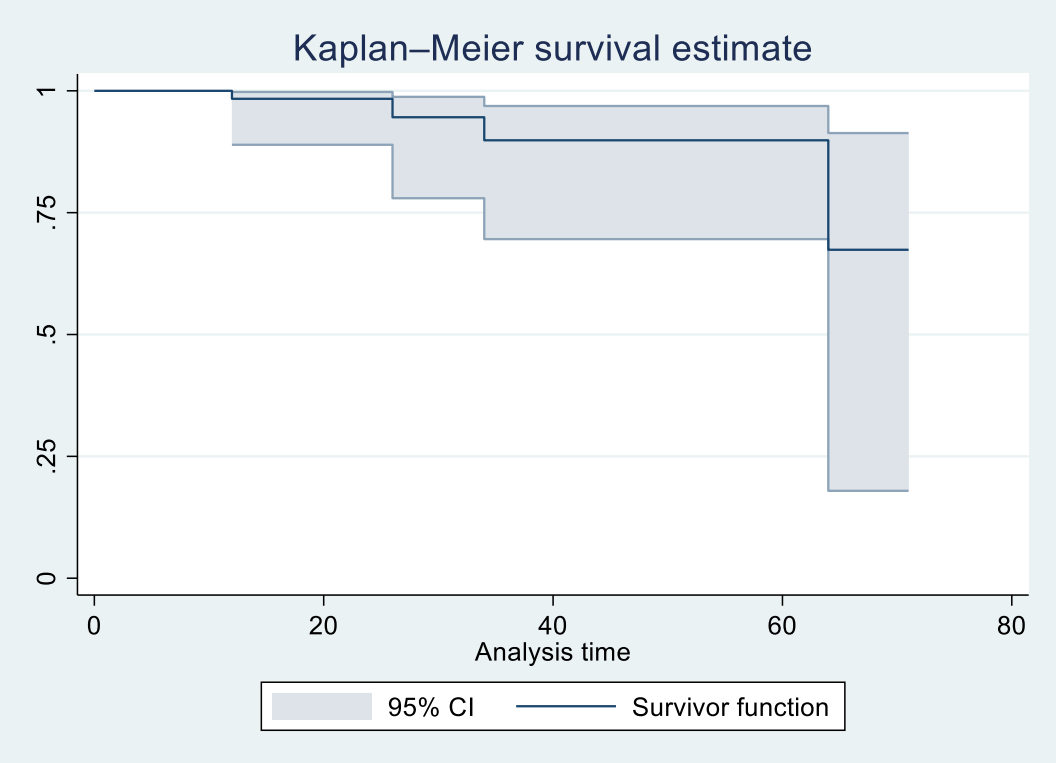

Figure 11. Kaplan-Meier curve for failure with a two-sided 95% confidence interval