CLINICAL OUTCOMES OF SINGLE IMPLANT-SUPPORTED VERSUS IMPLANT SUPPORTED-FIXED PROSTHESES IN DUBAI HEALTH AUTHORITY CLINIC

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ABSTRACT

Clinical Outcomes Of Single Implant-Supported Versus Implant Supported-Fixed Prostheses In Dubai Health Authority Clinic

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Background: Whether implant-supported fixed prostheses have worse clinical outcomes than single implant-supported prostheses is controversial.

Aim: This study aimed to assess the clinical outcomes of single implant-supported prostheses and implant-supported fixed prostheses placed in Al Badaa Dental Center in Dubai Health Authority (DHA).

Materials and methods: This retrospective study compared biological and technical complications among single implant-supported prostheses and implant-supported fixed prostheses in a time framed sample of all patients who received dental implants between January 2009 and December 2016. Cantilevered implants, implants supporting complete dentures or removal partial dentures and any case involving a sinus lift procedure or bone grafting were excluded. The records of all eligible cases were assessed for prosthetic complications including screw loosening or fracture and ceramic de-lamination. Mesial and distal bone height around the implants were measured on digital radiographs by one examiner.

Results: A total of 455 patients (151 males; 304 females) had 1673 implants. The mean age of males (53.7 years, SD 14.6) was significantly greater than that of females (49.3 years, SD 12.9, p<

0.001). The lower left and right posterior sextants were the most frequent sites for implants while the lower anterior sextant was the least common. Mean mesial crestal bone loss in implant supported-fixed prostheses was significantly greater (1.14mm, SD 0.63) compared to single implant-supported prostheses (0.30mm, SD 0.43, $p<0.001$). Mean distal crestal bone loss was also significantly greater (1.29mm, SD 0.71) in implant supported-fixed prostheses than in single implant-supported prostheses (0.36mm, SD 0.54, $p<0.001$). Mean crestal bone loss mesially and distally in patients with a medical condition (N=165) was significantly greater compared to medically fit patients (N=290, $p<0.001$). Mean mesial and distal bone loss was significantly greater around implants placed in the lower anterior sextant compared to all the other sites ($p<0.001$). A total of 66 cement retained implants had significantly more complications than expected compared to the 1607 screw retained implants (Fisher's Exact test, $p<0.001$).

Conclusion: Implant supported-fixed prostheses have greater bone loss than single implant-supported prostheses. Age, position in the mouth and having a medical condition are factors that influence bone loss.

DEDICATION

This dissertation is dedicated to the memory of my beloved father, who passes away before I started my journey in dentistry. My dear mother (**Aisha**) and my dear husband (**Ibrahim**) whose affection, love, sacrifices, encouragement and prays abled me to succeed.

To my cherished daughter (**Dana**) for enduring my ignorance and the patience she showed during my dissertation writing.

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And lastly above all to Allah (Almighty God), thanks for the guidance, strength, power of mind, and protection.

DECLARATION

I declare that all the content of this thesis is my own work. There is no conflict of interest with any other entity or organization

Name:

Signature:

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1. INTRODUCTION

Dental implantology is the field of dentistry that uses artificial tooth root made from titanium or zirconia to replace missing teeth. The field has grown in the past thirty years from experimental and unreliable treatment modalities to a recognized standard of care. The history of dental implant research is long and extensive with a variety of successful and failed materials, implant designs, surgical and prosthetic techniques, and clinical applications. Owing to the high success rates reported in clinical studies, dental implant supported fixed partial prostheses have been increasingly used as a treatment option in restoring partially edentulous patients[1,2].

Most research has evaluated the long-term effect of osseointegration of implants and the factors that affect the success of the treatment. When treating patients, clinicians tend to follow standard protocols that were established based on a well-documented clinical trials and reviews. However, in reality some clinicians tend to use clinical experience or peer to peer recommendations. It has been a dilemma for clinicians to decide whether implant-supported fixed prostheses or single implant-supported prostheses is the best treatment option[3,4,5].

According to the available literature, there are two major categories of complications that might occur in dental implants. First, biological complications that are defined as those associated with the implant placement and the healing of the surrounding structures. Second, technical complications which are defined as those associated with the prosthetic component of the implant or the prothesis itself[6,7].

2. REVIEW OF THE LITERATURE

2.1 Advantages and disadvantages of single implant-supported prostheses and implant-supported fixed prostheses

In the past, researchers advocated the use of implant-supported fixed prostheses to gain even load distribution, reduce marginal bone loss, and reduce prosthetic complications. Recent developments in dental implant design, implant surface properties, and improved surgical techniques have led researchers to advocate reconsideration of the assumption of implant-supported fixed prostheses[3,4,5].

Splinting dental implant prostheses or restoring them as a single prosthesis is a common but not simple decision that many clinicians need to make. This issue has usually been a source of dispute among dental practitioners[3,4,5]. Preferably, the decision should be done at the initial point during the treatment-planning phase, but in reality, it is done after the implants are inserted and sometimes at the time of taking the impressions[3,4,5]. The single implant-supported and implant-supported fixed prostheses controversy has been debated regarding implant length, implant angle, occlusion, framework passivity, ease of hygiene, and esthetic when planning to splint or not to splint the prostheses[3,4,5].

There is still no consensus in the literature regarding whether single implant-supported prostheses or implant-supported fixed prostheses is superior[8]. Some clinicians decide to use implant-supported fixed prostheses to avoid damaging occlusal forces on the prosthetic component and supporting structure in order to decrease the expected marginal bone loss or improve the esthetic outcome. On the other hand, many patients and clinicians prefer the single implant-supported prostheses due to better hygiene, thus maintaining a healthier environment for the implant and the surrounding structure. The evidence from previous studies comparing single implant-supported prostheses and implant-supported fixed prostheses are very weak[9,10,11]. According to the available evidence, implant-supported fixed prostheses may be superior in one situation but not advisable in another. It is up to the clinician to make their choice to use single or implant-supported fixed prostheses based on the clinical situation and the need to reduce possible complications. Brånemark introduced the concept of splinting dental implant prosthesis for mandibular complete edentulous patients. The entire all on four concepts utilize two tilted implants in the posterior region, and two straight implants in the anterior region, splinting them to create cross arch fixed restoration for complete edentulous patients[12,13]. The difference between single or implant-supported fixed prostheses has been studied via numerous methods including finite element analyses, photo-elastic model analyses, and clinical investigations. Nonetheless, there is no agreement whether a single or implant-supported fixed prostheses design is superior[8].

The primary advantage of free-standing dental implant prostheses is easier and thus more effective interproximal hygiene, reduction in the quantity of metal and ceramic, a better emergence profile, and if one unit is compromised, it can easily be removed for repair or remake[3,14,15]. Other researchers found that there is an increased risk of porcelain fracture in single implant-supported prostheses due to the presence of unsupported porcelain margins undergoing shear loads[3,14,15].

On the other hand, the advantages of implant-supported fixed prostheses in general are to increase the functional surface area for support, increase the load sharing regardless of the direction of the load especially for short dental implants in patients with parafunctional habits, increase cement retention of the prosthesis, reduce the risk of marginal bone loss, and reduce prosthetic complications[3]. Simply splinting adjacent implant protheses allows the distribution of the functional forces in a uniform manner to the implant which reduces the overload on the crestal bone that may lead to less biological and technical complications such as screw loosening, implant fracture and implant failure[3,4]. According to the literature, the reasons for splinting dental implant prostheses are the high incidence of loose screws in non-splinted and to share loads evenly[16,17,18,19]. Additionally, implant-supported fixed prostheses is indicated for patients without anterior guidance, parafunctional habits, and in patients with stabilized periodontitis[18,19,20]. While others suggested implant-supported fixed prostheses together in the following situations: when there are reduced number of natural occlusal stops, steep anterior guidance planes, parafunctional oral habits, implants restoring canines, fully edentulous maxilla and if the prosthetic components have compromised retention and resistance form especially cement retained prostheses[4,7,15].

Misch (2005) advocated splinting implant prostheses in order to reduce the number of implants needed with economic implications for the patient[20]. According to the literature, the rationale for implant-supported fixed prostheses were the high incidence of screw loosening in single implant-supported prostheses as it was reported that screw loosening in implant-supported fixed prostheses was less frequent. A prevalence of 8% for implant-supported fixed prostheses in comparison with 48% for single implant-supported prostheses has been reported[3], plus implant-supported fixed prostheses had even load sharing and distribution[17,18,19,21].

Unlike teeth, dental implants are incapable of moving in response to eccentric forces. Forces transferred to implants are concentrated in the coronal 2 to 3mm of crestal bone surrounding an implant[22]. Additionally, overloading may produce micro-fractures of crestal bone, mechanical failure and fracture of the implant or fatigue fractures of the prosthetic components[23]. Therefore, two posterior implants splinted together might aid to protect against the damaging effects of eccentric loading in the mesio- distal direction and distribute forces over a greater implant surface area in the bucco-lingual direction[22,24].

According to the available literature, single implant-supported prostheses permitted better inter-proximal hygiene in comparison to implant-supported fixed prostheses, and the latter require adjunctive oral hygiene aids such as super floss or interproximal brushes. Plaque accumulation between implants will not cause dental caries, but can lead to calculus formation and peri-mucositis or peri-implantitis with subsequent bone loss around the implants[23].

2.2 Framework fit in single implant-supported prostheses and implant-supported fixed prostheses

The effect of splinting and inter-proximal contact tightness between splinted implant prostheses was investigated by Guichet et al, (2002) who reported difficulty in achieving a passive framework fit in restoring multiple implants with implant-supported fixed prostheses[17]. A possible solution to this is to avoid splinting the implant prostheses, however there are several inter-proximal contacts that demand careful and accurate adjustments. Accordingly, it is more important to achieve a passive ideal inter-proximal contact between implants than between natural teeth due to the lack of periodontal ligament around implants and reduced dynamic response. Guichet et al, (2002) examined three implants restored and loaded either with splinted implant prostheses or with non-splinted implant prostheses of variable interproximal contact tightness using photo-elastic model of a human mandible loaded and analyzed with a polariscope[17]. They discovered that single implant-supported prostheses with heavy inter proximal contacts showed increased tensile stresses between implants[17]. They also found that implant-supported fixed prostheses disseminated the occlusal loads more evenly and off axis loading of implants was evenly shared by splinted prostheses[17]. It was concluded that individual crowns with excessively tight contacts can produce a similar clinical situation to a non-passively fitting framework in an implant-supported fixed prostheses[17].

An important issue was seen in implant-supported fixed prostheses where the prostheses may be completely seated on one implant while the others are not. A retrospective study has not demonstrated that poorly fitting prostheses lead to crestal bone responses compared to implants restored with well-fitting prostheses[25]. It was concluded that poorly fitting prostheses may not cause an adverse bone reaction under static strain thus, it may magnify dynamic parafunctional occlusal loads[25]. While others researches described that poor fit of the prostheses may increase the fatigue of the implant component and reduce their critical failure load[26].

2.3 Survival rate of single implant-supported prostheses and implant-supported fixed prostheses

A meta-analysis to estimate the survival rate of implants supporting fixed partial dentures and single implants in partially dentate patients a meta-analysis included nine studies with single tooth implants and ten studies with implant supported fixed partial dentures[26]. A total of 2686 implants containing 570 single crowns and 2116 implant supported fixed partial dentures were assessed with follow up periods ranged from 1 to 8 years[26]. After 1 year, they found 85% success rate for implant supported fixed partial dentures and 97.2% for single implants whereas the survival rate after 6-7 years for implant supported fixed partial dentures was 93.6% and 97.5% for single implants[26].

Likewise, a longitudinal study reported on 1956 implants, including 846 in the posterior region, 235 supporting single unit prostheses and 409 fixed partial dentures implant supported[27]. They estimated a 97.2% survival rate for implant supported fixed partial dentures after 16 years in function regardless of the implant position (anterior versus posterior)[27]. Moreover, they found that short implant length, high number of implants for every patient, a smaller number of implants per prostheses, implants loaded by acrylic veneered restoration and implants combined with bone grafting developed a higher risk for implant failure[27].

2.4 Crestal bone loss around single implant-supported prostheses and implant-supported fixed prostheses

A 5-year prospective study using non-submerged hollow and solid screw implants to assess splinted and non-splinted prostheses found that single implant prostheses exhibited 2.64mm of bone loss whereas in splinted prostheses it was 2.90mm of bone loss, the cumulative difference was 0.2mm which is not clinically significant[28]. A comparison of load transfer between splinted and non-splinted dental implants, found even load distribution and greater load sharing in splinted versus non-splinted dental implants[29]. In addition, others found that stress distribution among splinted dental implants is affected by implant diameter but there is no difference in stress distribution when splinting two implants with the same diameter[18]. Whereas splinting two implants with different diameters resulted in increased stress distribution towards the posterior prostheses[18]. Additionally, it is better to splint dental implants when the crown to implant ratio is unfavorable as it will affect the force transmission to the dental implant[3].

Despite careful surgical and prosthetic protocols marginal bone loss around dental implants can occur overtime. Evaluating the marginal bone loss in radiographs is a tool often used by researchers and clinicians to evaluate implant success or failure. The loss of 2mm of bone around the implant neck during the first year after functional loading has been considered normal by the dental community and has been contemplated as a successful outcome[30,31]. However, tissue stability at 1 year after implant placement and a loss of more than 0.2mm per year is undesirable[32]. Other authors have claimed that marginal bone loss in the first year of 1.5mm[33], 1.8mm[34], or 1.5 to 2mm[35] also characterizes a good outcome.

The evidence in the literature is that implant-supported fixed prostheses allows better load distribution and therefore reduced marginal bone loss[18,19]. In contrast others found that implant-supported fixed prostheses have greater crestal bone loss[36]. Moreover, it was reported that single implant-supported prostheses are subjected to higher forces but still can maintain their marginal bone level[8,14]. However, a 10 year randomized controlled trial evaluating the marginal bone level changes around multiple adjacent dental implants restored with implant-supported fixed prostheses versus single implant-supported prostheses found that there is a mean of 0.7mm marginal bone loss around implant-supported fixed prostheses and a mean of 0.8mm marginal bone loss around single implant-supported prostheses, the 0.1mm difference was not considered clinically significant[37]. Additionally, others found no significant difference in bone loss around splinted and non-splinted dental implants[5]. On the other hand, it was reported that implant-supported fixed prostheses showed greater crestal bone loss of 0.2mm compared to single implant-supported prostheses[36]. However, there was bone gain in non-splinted dental implants at 24-36 months[5]. Nonetheless, with the introduction of more textured implant surfaces, and modified implant designs, such as crestal micro-threads or platform-switching, this older principle no longer stands up to inspection. Certainly, many newer implant designs showed stable bone levels regardless of time in function if optimal treatment has been provided from the start[38].

2.5 Etiology of crestal bone loss around dental implants

Several factors contribute to peri-implant crestal bone loss, such as surgical and anatomical factors, patient risk factors, biological width, implant surface design, and biomechanical factors[3,9,39]. There is normally a direct rigid connection between the osseointegrated dental implant and the surrounding bone. Forces directed through the dental implant are transferred directly to the bone and may cause micro damage to the bone and marginal bone loss[3]. Surgical and anatomical factors include initial flap design, alveolar ridge bone thickness especially the buccal bone, one-stage versus two-stage implant placement and bone quality, density and vascularity[3,9,39]. Whereas for the patient risk factors include smoking and alcohol consumption, history of periodontitis, genetics, diabetes mellitus, poor oral hygiene and inadequate or irregular supportive periodontal care[3,9,39]. Factors related to biologic width include the location of the implant fixture to the prosthetic abutment connection micro-gap, the use of platform switching technique, the early unwanted exposure of cover screws and the implant to tooth or inter-implant distance[3,9,39]. Moreover, implant surface roughness and transgingival collar design may influence crestal bone levels. Finally, biomechanical factors such as functional overloading, prosthetic design, parafunctional habits and the presence of prosthetic cantilevers may have significant effects[3,9,39]. The etiology of crestal bone loss will be discussed in greater detail in the following sections.

2.5.1 Surgical trauma

The classical and recent literature proposed that surgical trauma is one of the possible etiologies for early peri-implant crestal bone loss due to heat formation from burs during the osteotomy preparation[40]. It has been found that bone temperature increased with increasing force whilst using surgical burs rather than being related to speed of drilling[40]. Moreover, it has been discovered that 47°C for 1 minute or 40°C for 7 minutes were the critical temperatures for overheating bone and impairing osseointegration[40]. The crestal bone level of an implant is located in cortical bone which is less vascular than trabecular bone. Cortical bone is often hard to drill and obliges increased drilling force for penetration and enlargement. Therefore, a combination of drilling force and excessive heat over time in cortical bone can damage the implant osteotomy and inhibit osseointegration of the implant[40].

2.5.2 Occlusal trauma

Occlusal overload of implants has also been discussed in the literature as it results in implant bending, high compressive stresses on bone surfaces, and bone micro fractures that could accelerate bone remodeling and loss[40,41]. The concept of micro-fractures in bone around dental implants was first described in 1989[41]. It was suggested that high stress bearing areas like the crestal bone around implants may undergo micro fractures, bone resorption and formation of crestal bone cavities[41]. Implant overloading can be due to a large prosthesis that is supported by 1 or 2 implants in the posterior area, poor vertical alignment of implants, excessive cantilever lengths, differences in dimensions between occlusal table and implant head, and parafunctional habits[3,9,39]. Others suggested that stresses in peri-implant crestal bone during early function of the implant may result in micro fractures, as it has been noticed that during the first year of implant function there is often crestal bone loss[42]. Thereafter, progressive implant loading was recommended to avoid early crestal bone micro fracture and any changes in bone density and strength occur as a result of loading during the first year which may cause changes in the stress strain relationship and reduce the risk of micro fracture in the following years[42].

2.5.3 Microbiological and host response

Crestal bone loss can happen as a result of peri-implantitis, which is a site-specific infection with microbial features unlike those found in chronic periodontitis and involves pathogens such as gram-negative anaerobic rods, bacteroids, fusobacterim and spirochetes[43]. Clinical criteria used to detect peri-implantitis are as follows: radiographic evidence of progressive crestal bone loss, formation of deep peri implant pocket, bleeding after gentle probing with possible suppuration, mucosal swelling and redness[43]. It is distinguished from peri-implant mucositis which is a reversible inflammatory lesion confined to peri-implant mucosal tissues without bone loss[43]. Peri-implantitis is still under investigation as its etiology and pathogenesis is similar to periodontitis, but the treatment is not as predictable.

2.5.4 Biological width and micro-gap

The implant fixture or implant micro-gap and prosthetic abutment connection have been associated with crestal bone loss and peri-implantitis due to accumulation of bacterial deposits[44]. The effect of the micro-gap was compared in a 1-piece single stage with 2-piece two stage titanium plasma spray threaded implant and the result that bone levels around a 1-piece single stage were generally at the level of the smooth rough surface junction of the implant whereas in conventional two stage implants the crestal bone level was consistently 2mm apical to the micro-gap[45].

To overcome the micro-gap or implant fixture and prosthetic abutment connection the concept of platform switching was introduced by Lazzara et al, (2006) by distancing the micro-gap from the alveolar bone[45]. They observed that the inward horizontal repositioning of the implant abutment interface by using regular diameter (4mm) prosthetic abutments on wide body (5mm) diameter implants developed less crestal bone loss[45]. This concept added a horizontal component to the implant surface to accommodate for the biological width formation which is the major driving force behind the initial bone remodeling around the implants[45].

The biological width is defined as a minimum width of mucosal tissue needed to form an effective barrier to protect the supporting bone is identified in both natural teeth and implants[46]. It has been discovered that after implant placement and exposure to the oral cavity, crestal bone remodeling follows there is adequate implant surface exposed to accommodate a liner contact of implant surface to soft tissue[46]. Studies had found that after 1 year of loading, threaded implants in dogs had a biological width of 3.08mm (1.88 mm of junctional epithelium and 1.05mm for connective tissue)[46]. Nonetheless, newer implant designs that incorporated crestal micro threads and or platform switching showed less vertical crestal bone loss to adapt to the newer biological width formation[46].

2.5.5 Implant design

Implant design also impacts crestal bone loss. Among early implant designs the coronal neck area was designed to reduce plaque accumulation by having a machined or polished smooth surface finish. The effect of depth placement of 1-piece rough surfaced threaded implant with machined transgingival collar regions were implants positioned in a dog mandible either with smooth or rough joint at the crest of bone or 1.5mm apical to the crest[47]. Implants placed 1.5mm sub-crestal in dog mandibles had 1.5mm crestal bone loss to adapt for the biological width formation. Newer implant collar designs frequently have an acid washed or laser etched moderately roughened surface to induce gentle crestal bone loading and avoid breakdown that is promoted with the polished collar design[47].

According to Albrektsson et al, (1986) it is normal to have bone loss to the level of the first thread of the dental implants due to natural forces around the implants[32]. Cortical bone is the most resistant to compression forces, 30% weaker to tensile forces, and 65% weaker to shear forces[48]. Moreover, it was reported that implants with smooth collar designs only transmit shear forces to bone[42]. Crestal bone loss stabilizes after the first thread becomes exposed due to a change from shear force to compressive force in which bone is more resistant at the crestal bone region[42]. Moreover, others stated that micro-fractures resulting from localized high stress concentrations lead to resorption of crestal bone on compressive surfaces adjacent to a threaded implant that is subjected to controlled off-axis loading[49]. Another aspect implant design, is implant thread geometry, that the functional surface area per unit length of an implant is affected by thread geometry[42]. According to the evidence in the literature, the functional surface area disseminates the compressive and tensile loads through the implant to the bone interface during loading[50]. Thus, long threaded implants of more than 8mm perform better than short threaded implants less than 8mm[50]. Thread pitch, thread shape, and thread depth contributes to thread geometry and will be discussed in greater detail. The thread pitch is defined as the distance between neighboring threads[51]. The smaller the pitch, the more threads on the implant surface and thus an increase in the surface area[51]. Secondly, the thread shape has three types: V-shape, reverse buttress, and square[51]. The V-shape is used for fixation devices like bone plates, whereas the reverse buttress has flat top to improve resistance to pullout loads and the square thread offers optimal surface area for compressive load transmission[51]. The shear forces for V-shape threads are ten times greater than for the square shaped threads[51]. Therefore, it is important to reduce the shear loading at the bone to thread interface under high occlusal loads especially in the posterior region[51]. Finally, the thread depth which is defined as the distance between the widest and narrowest diameters of the thread. While the thread depth increases the implant surface area increases as well[51]. Hence, V-shape and the broader square thread shape produce significantly less stress compared with the thin and narrower square thread in cancellous bone[51]. Researchers recommended the utilization of different thread designs along the length of the implant to provide more functional surface area in regions of highest stress[52]. Therefore, implant design features contribute and influence peri-implant crestal bone remodeling after loading.

2.5.6 Bone response

Wolff's Law describes the intrinsic capability of bone adaptation to surrounding structures and forces[53]. It states that there is close relationship between mechanical loading and bone strength and it has great effect on bone deposition and resorption[53]. The stresses placed on the bone encourage healing, providing that the micromotion created does not exceed the acceptable interfragmentary strain for osteoid deposition. While if the mechanical loads exceed the strength of the reparative capacity inhibition of bone healing or fractures can occur[53]. The application of this concept in relation to the placement of dental implants and bone interaction have been perceived in several ways. Movement of up to 100 microns can be tolerated before fibrous tissue repair before bone formation and osseointegration develops[54]. Fibrin clot attachment and organization is hindered because of micromotion, which in return affects the angiogenesis of tissue healing and the migration of regenerative cells to that region. Therefore, it is the absence of excessive micromotion at the bone implant interface that is more critical for osseointegration of the implant instead of the absence of loading during the initial phase of healing[55]. On the other hand, a study on Sinclair pigs to assess the osseointegrated bone changes for 2 healing times (between implant insertion and loading) after 5 months of loading[56]. They concluded that early loading preserves the most crestal bone while delayed loading has significant crestal bone loss with the non-loaded implants[56]. So, reasons for crestal bone loss is associated with several variables including surgical placement technique, implant design, thread design, occlusal forces, to patient related factors.

2.6 The effect of implant dimensions on implant success and survival

In 2016 the European Association of Dental Implantologists updated their definition of short implants as follows, implants with intra-bony length ≤ 8mm and with diameters ≥ 3.75mm while standard implants are defined as implants with intra-bony length >8mm and diameters ≥3.75mm[57]. Ultra-short implants are defined as implants with intra-bony length < 6mm[57].

Early studies found an increased failure rate with short implants which was linked to the skills of the operator, machine surface implant finish and poor bone quality[58,59]. However, recent studies in relation to surface treatment of implants such as particle blasting and acid etch revealed comparable survival rate of short and long implants[59,60]. On the other hand, a recent systematic to assess the long-term clinical performance of short and ultra-short implants concluded that short implants are a viable and successful treatment option with cumulative survival rate ranging from 84% at 5 years to 100% at 2 to 10 years, with mean overall failure rate 3.9%[61].

Implant success is defined as implants with vertical bone loss not greater than 1.5mm in the first year of loading and 0.2mm annually[32]. In the next section, criteria such as implant length and implant diameter and its effect on implant success and survival will be discussed in more detail.

2.6.1 Implant length

The impact of implant length and diameter on survival rate of implants was reviewed in 13 papers published between 1990 until 2005 with the finding that 7mm long threaded machine surfaced implants had a 25% failure rate and short implants tended to fail significantly more frequently following uncovering and after loading than long implants[62]. The reasons for the high failure rate included the use of routine surgical protocols irrespective of bone quality[62]. Conversely, others reviewed 732 threaded machined surface implants and reported that the failure rate in 7mm long implants was 9.5% but 3.8% for short implant length[63]. Moreover, other studies also showed acceptable results in relation for short implants while using an adapted surgical protocol to improve primary stability such as not using a countersink in bone with lower density[64,65].

In addition, researchers compared short implants placed in severely resorbed jaws and found that jaw shape and bone quality adversely affect implant survival specially when short implants are placed in poor bone quality[66]. Furthermore, others concluded that longer wider machine surfaced implants failed less than short standard diameter (3.75mm) implants again in patients with poor bone quality[67]. Multiple studies have discussed the overall survival rate of short implants mainly 7mm in length and reported the following: 99.2% over a mean follow-up period of 31 ± 12.3 months[59]. Likewise, Friberg et al, (1991) reported 94.5% survival rate for 7mm long Brånemark implants[67], whilst others stated that the mean marginal bone loss for 7mm long implants placed using modified surgical protocol is only 0.44 +/- 0.52 mm after 2 years of function[62].

Meanwhile, due to the anatomical limitation in the posterior area where the vertical bone height is limited due to the presence of the mandibular neurovascular canal and maxillary sinus, the use of short implants has increased. The use of short implants with modern designs and surgical techniques has a similar success rate to standard length implants[68].

2.6.2 Implant diameter

Studies has found that wide diameter implants in the mandible had 94.5% better results than in the maxilla 78.3%[69]. The cumulative survival rate in the maxilla have been reported as 97.2% and in mandible 83.4% using wide diameter implants[70]. The overall survival of 3mm implants was 90.7% and for 4mm implant it was 94.6%[71]. Others explained the reasons behind the higher failure rates in wide diameter implants as they were placed in areas where primary stability could not be achieved with standard diameter implants and in posterior regions where bone quality is poor[57]. Therefore, selecting an appropriate implant width according to the available width of the edentulous ridge has predictable results.

2.7 Radiographic measurement of crestal bone loss

Different radiographic techniques to measure crestal bone levels around implants have been recommended. These techniques include digital and conventional periapical and horizontal bitewings, panoramic radiographs and cone beam computerized tomography, although there is limited evidence to compare which method is more accurate[27,71,72]. The changes in crestal bone level around implants can be evaluated in relation to a stable landmark such as implant threads and implant abutment interfaces.

According to the literature, the methods for measuring radiographs to assess the crestal bone loss refer to the number of exposed threads or in millimetric values from a reference point[27,71,72]. This can be done on plain films with the use of magnification and conventional rulers or digital calipers[27,71,72]. Additionally, radiographs can be digitalized and measurements can be done with computer software that utilizes calibration of known dimensions such as the implant length[27,71,72]. Many implant designs incorporate a smooth collar into their implant design and it is considered as part of the intraosseous implant length[27,71,72].

A longitudinal study with 5.1 years follow-up of implants in function ranging from 1 to 16 years assessed the crestal bone loss in relation to implant abutment connection using radiographs taken with the parallel cone technique[36]. The study included implants with single crowns, prostheses connected to teeth and implant supported fixed partial dentures (bridges) and concluded that single (non-splinted) implant crowns did not have more marginal bone loss than that seen around splinted implants[36]. Moreover, the study included implants in both anterior and posterior regions of the mouth and found no difference in crestal bone loss[36]. However, the study concluded that non-splinted implant prostheses had less marginal bone loss than those with splinted implants, and there was no difference in crestal bone loss in relation to implant length. A mean bone loss of 1.23mm loss of bone in the first 6 months with annual loss of 0.025mm which confirmed other reports was also found[36]. The study estimated there was more bone loss in the maxilla than in the mandible which was greater by 0.31mm/year during the first year of loading[36]. On the other hand, they found bone gain with 14.57% of implants while 98.75% of implants had less than 3mm bone loss, 92.43% had less than 2mm and 64% had less than 1mm[36]. Additionally, others confirmed these results as the mean crestal bone loss during the first year was 0.9mm and 0.1mm annually[73].

They also found that 1.5% of implants lost more than 2mm over 3 years, 23% lost 0.1-0.5mm, 34% had no bone loss yet 19% had bone gain[73].

2.7.1 Comparison of radiographic techniques in measuring crestal bone loss

The radiographic technique used in many studies measuring bone loss was not standard. Smith & Zarb (1989) advocated standardized serial radiographs with the use of a positioning device to ensure the x-ray beam is at right angles to the long axis of an implant[74]. Other scholars utilized a film holder device and screwed it directly to the implant after superstructure removal. Numerous approaches have been developed to improve and standardize the projection geometry of serial radiographs[75,76]. The importance of reliable longitudinal radiographs was highlighted in studies that showed a 1° deviation between exposures of two sequential radiographs can result in crestal bone level difference of 0.09-0.25mm[77].

Comparing crestal bone loss levels using intraoral periapical radiographs and panoramic radiographs of implants in the mandible with two observers showed that intra-observer agreement was very good and inter-observer agreement was moderately good[72]. Furthermore, it was found that 7% of the radiographs could not be assessed due to poor film quality and it was noted than panoramic radiographs gave unreliable magnification and distortion[72]. On the other hand, others compared crestal bone loss 1 year after loading the implants using conventional intraoral periapical radiographs, digital radiographs and panoramic radiographs and measured 0.76mm of bone loss with conventional intraoral preapical radiographs, 0.95mm with digital intraoral preapical radiographs, and 1.36mm of bone loss with panoramic radiographs[78]. Moreover, there was more bone loss in the maxilla and in smokers[78]. It was concluded that conventional and digital intraoral preapical radiographs were more accurate than panoramic radiographs[78].

Others compared intraoral periapical radiographs with narrow-beam panoramic radiographs and found that there was better agreement in posterior areas[79]. However, they did not measure the crestal bone loss in millimeters, but rather by the number of exposed threads[79]. Others found a 0.2mm error between intraoral periapical radiographs and panoramic radiographs[80], on implants placed in human cadavers on radiographs taken with conventional and digital intraoral periapical radiographs and panoramic radiographs. In addition, measurements were made on the actual bone loss around the implants for comparison reasons[80]. The researchers arrived at the conclusion that measurements of crestal bone loss were more accurate with intraoral preapical radiographs[80]. Additionally, other studies confirmed that intraoral periapical radiographs were more accurate than panoramic radiographs or cone beam computerized tomography in measuring the implant length and as a reliable modality for longitudinal and linear distance measurement[78].

2.7.2 Recommended clinical guidelines for implant radiographs

The significance of taking radiographs at the time of implant placement is that it serves as a baseline record of peri-implant structures and provides medico-legal proof of the procedure. It is also recommended that there should be a designated member of the clinical team who is responsible for taking all implant radiographs to improve the comparability of serial radiographs. Albrektsson, et al, (1986) recommended guidelines on the frequency of implant radiography. It is recommended to take an x-ray 1 week after second stage surgery, at the time of prostheses insertion, 6 months after prostheses insertion, annually for 3 years thereafter and if no complication occurred, then after every subsequent two years[32]. Moreover, it is recommended that two exposures at a 6-12° variance in the horizontal plane may help in detecting any boney defect that may occur by the implant in a single exposure[32].

There are several issues with getting reproducible parallel film placement. The most common issue is a shallow mandibular vestibule or palatal vault, which hinders the proper placement of the film[81]. To overcome this issue, some experts suggested the use of two films, whereby one film assists to capture the entire implant length but is not parallel to it. The second film must be parallel only to the coronal part of the implant comprising the crestal bone area[81]. Another technique is to use a cotton roll between the film holder bite block and the occlusal surface of the teeth that is when the file length in relation to occlusal-vestibular dimension is too large[81]. A second source of error in radiography is the way in which the patient bites on the film holder bite block[81]. For example, if a patient bites more facially or lingually on the block the relation of the mandibular teeth in relation to the maxillary teeth may cause the film holder to stray from its parallel position in relation to the long axis of the implant[81]. Hence, although there are numerous recommendations described in the literature, these studies show no or little consensus.

2.8 Finite element analysis of peri-implant force distribution

Finite element analysis has become a progressively useful means for the prediction of the effects of stress on the implant and its surrounding bone. It is a tool used in an attempt to understand implant performance[82]. It has seen use since 1976 whereby it has helped to simulate the effect of different materials, designs, and forces that affect dental implants[83]. According to this analysis, the materials are defined by their mechanical properties such as Young's modulus. On the other hand, it has its own limitation since it is based on a virtual representation of clinical scenario, and results depend on the quality of data used to create the virtual simulation[53].

2.8.1 Finite element analysis and implant length

One of the aims of finite element analysis studies is to explore stress and strain patterns and concentration areas around implants. Researchers have considered the effect of implant length and diameter with different prosthesis designs and forces. One study investigated the effect of implant length and diameter prior to and after ossointegration and concluded that irrespective of the integration phase, as the implant length increase, the stress on the implant to bone interface end up decreasing[84]. Moreover, the delayed loading only has effects on trabecular bone and none on the cortical bone[84]. Furthermore, the study showed no correlation between the influence of implant diameter and stress reduction[84]. In another study, five different implant designs were evaluated through three-dimensional finite element analysis in the posterior maxilla and mandible[21]. Different implant types (ITI, Noble Biocare, and Ankylos) with different implant diameter ranging from 3.3mm to 4.5mm and lengths ranging from 7.5mm to 12mm were loaded statically with vertical and horizontal components[21]. However, some of the postulations are questionable given that the assumed factors such as bone quality, level of osseointegration, and type of forces may not replicate in vivo conditions accurately[21]. Hence, it was concluded that supreme stress in the peri-implant area was near the implant neck while potential overloading may occur with the compression of compact bone and tension at the junction of cortical and cancellous bone. Further, it was found that increasing implant length improved the stress distribution while increasing implant diameter decreased the stress transmitted in the cortical bone[21].

The influence of implant length and bicortical anchorage on peri-implant stress distribution was also investigated[85]. The study involved 3.75mm diameter implants of different lengths, ranging from 6mm to 12mm positioned in cortical and cancellous bone and loaded with occlusal forces of 100N at 30° angle[85]. It was established that bone stresses are concentrated in the coronal cortical anchorage region while the stress is located at the neck level irrespective of implant length[85]. Beyond the coronal region by 4mm, stress intensity was low and peak stress was placed at the inferior groove of the first thread[85]. The outcome of bicortical anchorage reduced displacement of the implant at the neck level and displacement of short implants was seen more[85]. Thus, long implants are more likely to bend whereas short implants are more likely to rotate[85].

The design efficacy of the Indigenous titanium dental implant "INDIDENT" using finite element stress analysis was evaluated[86]. Using models with three different types of implants resembling external hex, internal hex, and ball and socket type in order to calculate the stress generated[86]. The effect of various implants lengths (8mm, 10mm, and 12mm) found that stress concentration and distribution is not affected by the length[86]. On the contrary implant diameter is more important than the length in the distribution of loads to the surrounding bone[86]. As four various implant diameters (3.5mm, 3.8mm, 4.2mm and 5mm) were also measured. As implant diameter increases the contact surface also increases and instantaneously stress patterns decrease[86]. Thus, increasing implant diameter successfully increases the contact area between implant and bone and this might eventually increase the stability of the implant[86]. Others found that angulated implants experience five times higher compressive stress around cervical bone than non-angulated implants and stress values with oblique loading forces being higher than the values with vertical loading forces[87].

Finite element analysis has identified factors that might affect bone implant stress distribution as implant inclination, number of implants and their location, prosthetic splinting scheme, occlusal surface areas, framework materials and shape of the prosthetic framework[82].

2.8.2 Finite element analysis comparing splinted and non-splinted implant prostheses

Three-dimensional finite element analysis was conducted on molar teeth that were replaced with either 3.75mm or 5mm diameter implant versus two 3.75mm diameter implants[88]. They were loaded with 35N and 70N at three various locations on the implant and axially and 15° off axis[88]. It was concluded that 5mm diameter implant reduces abutment strain by 40% when compared to single 3.75mm diameter implant[88]. Moreover, it was found that a single missing mandibular molar should be replaced with a wide diameter implant or two standard diameter implants[88]. Non-axially loaded double implants had less micromotion of the crown implant unit than a single wide diameter implant design[88]. Additionally, the study concluded that increasing implant width in single implant supported prostheses from 3.75mm to 5mm result in 50% reduction in micromotion of the fixture[88]. Others have concluded the same results and they found that angulated force resulted in larger bending strains[89]. They also recommended that increasing implant number and diameter may effectively reduce implant abutment strain[89]. Other researchers suggested clinical solutions such as concentrating the occlusal forces as close to the bucco-lingual center of the implant by narrowing the occlusal table, directing the maximum intercuspal contact along the central groove of the crowns, and eliminating eccentric occlusal forces[88].

Multiple studies have examined wide diameter implants using finite element analysis and clinical analysis. Two adjacent implants with different diameter size (3.75mm and 5mm) in premolar and molar areas of a cadaver mandible included splinted or non-splinted prostheses, were investigated using finite element analysis[90]. Implants were modeled as cylindrical roots but not with threaded surface geometry and in a simulated mandible with cortical and cancellous layers[90]. The finite element analysis was conducted via strain gauge measurements on the cadaver mandible. The results showed that when splinted molar crowns were supported by either, a wide diameter or two standard diameter implants, the bone stress in the premolar area decreased by 25%[90]. It was also evident that wider implants or two splinted implants reduced peak stress in crestal bone by 29% to 37% in comparison to a single standard diameter implant[90]. Furthermore, when standard 3.75mm diameter implants were placed in premolar and molar areas either splinted or non-splinted, the bone stresses were identical[90]. In addition, the stress on cortical bone around the first molar implant when splinted with a wide 5mm diameter or two standard 3.75mm diameter implants decreased by about 30% in comparison to a standard diameter implant in the molar area[90]. It was concluded that splinting two wide diameter implants or splinting two standard diameter implants both have identical load sharing whereas splinting different implant diameter share different load [90]. Another study confirmed similar results that micromotion is better controlled in double implants in comparison to a single wide diameter implant. And that there is a reduction in stress and strain for double implants in comparison to one wide diameter implant[91].

2.9 Clinical assessment of implant success versus implant survival

In the literature, implant success and implant survival have different and distinct meanings. These two definitions are sometimes misused. A brief literature review of clinical parameters to evaluate long term implant survival and success will be discussed in greater detail in this section. The first criteria of implant success were defined in 1979 as follows. First, the implant should display mobility less than 1 mm in any direction[32]. Second, there should be no bone loss greater than one third of the vertical bone height[32]. Third, there should be no symptoms, no infection, nor damage to the adjacent teeth[32]. Fourth, there should be no paresthesia and no damage to the mandibular canal, maxillary sinus, as well as the nasal floor[32]. Fifth, the implant should function in the patient's mouth for five years[32]. Further criteria were added in 1982 that there should be no evidence of radiolucency on the radiograph and patients should have no pain from the implant[92]. Hence, the survival of an implant is defined as continued functionality of the implant in the absence of clinical mobility, radiographic evidence of pathology, unresolved pain, discomfort or infection[93]. Implant failure is defined as removal of the implant for any reason[93].

It has been suggested that success and survival imply that osseointegration has been achieved and is maintained during functional loading[94]. All implants should be tested for individual implant mobility, which would include removal of all splinted prostheses, and a recent radiograph should show no more than 1mm of crestal bone loss after the first year of implant loading and no more than 0.2mm crestal bone loss per year thereafter[94]. The term survival is applied to all retrospective studies which include implants that are in the mouth but may not have been tested for mobility or assessed annually[94]. Therefore, it is important to differentiate between the two terms of survival and success. Implant success means implants are not only in the mouth but are also functional and satisfactory for the patient while implant survival means that implants are still in the mouth at the time of examination regardless of the state of the prostheses or patient satisfaction.

2.9.1 Peri-implant hard tissues

According to Albrektsson et al, (1986) implant success criteria suggest that a successful implant has to be immobile when tested clinically, with no evidence of peri-implant radiolucency on recent radiographs, show no more than 0.2mm of vertical crestal bone loss annually, and has no persistent or irreversible signs and symptoms of pain, infection, neuropathies, paresthesia or violation of the mandibular canal[32]. Suggestions by Smith and Zarb in 1989 also define success rates of implants whereby they agree with Albrektsson, but recommend that implants that are placed but left submerged and are not functional for multiple reasons require exclusion from all determination of success[74]. Further, complications that are of an iatrogenic nature such as poor surgical placement but not due to material or design problems to be considered separately when evaluating the success rate[74].

2.9.2 Implant mobility

Initially implant mobility was checked using two dental hand instruments. Later on, the Periotest device was used to measure tooth mobility and implant mobility[94]. The Periotest can be described as a hand piece containing a metal slug that accelerates towards the tooth or implant. The contact duration of the slug on the tooth or implant is measured by the Periotest and quantified in a range of values -6 to +2. The lower the Periotest value the more stable the tooth or implant. The test shows decreasing values over time after insertion of an implant, which is consistent with bone remodeling around the implant[94]. According to the literature, the Periotest has 84% sensitivity and 39% specificity[94]. Moreover, the Periotest at the start of the surgery offers high sensitivity in the prognosis of early implant loss and shows greater capability to evaluate the stability of implants during the ossointegration phase in comparison with radiographs[94].

Recently the resonance frequency analysis replaced the Periotest in clinical research with implants. Introduced in 1996, it consisted of device that was screwed onto the implant and connected to a monitor via cables. Nowadays, the design has been changed into a wireless machine with an aluminum peg that is screwed into the implant[95]. A transducer produces a resonance frequency on the implant which is measured in implant stability quotient (ISQ) units, a high ISO value like 60 and more is a sign of a successfully integrated implant[95]. The resonance frequency analysis value is affected by the stiffness of the bone implant complex, the jaw containing the implant, patient's gender, and implant length and diameter. In one study, 75 one-stage implants were assessed with resonance frequency analysis at time of placement[96]. Several of the implants showed a decrease in ISQ values during the study[96]. However, unloading these implants improved their ISQ values[96]. Likewise, others evaluated the resonance frequency analysis on 72 immediately loaded implants and found that implants with decreasing stability showed a continuous decrease in ISQ values until clinical failure[97].

The validity of both Periotest and resonance frequency analysis to estimate the bone implant contact interface found that both methods give inconsistent results due to other contributing factors such as bone density, jaw location, abutment length and supra-crestal implant length[98].

2.9.3 Peri-implant soft tissues

There is a debate about the relevance of peri-implant mucosal health as an indicator of implant success. Early studies questioned the validity of classical periodontal indices and the importance of the peri-implant soft tissue seal[81,99,100]. Some suggested the use of the plaque index to monitor oral hygiene due the fact that the primary etiological factor in peri-implant destruction was plaque[81]. Other investigators reported that the width and thickness of the peri-implant keratinized mucosa is a crucial factor in long-term implant health and success. According to the classical literature, probing depths were the most accurate measurement for peri-implant destruction[101]. They advocated that probing depths should include measurement of soft attachment levels and be measured relative to a fixed reference point on the abutment or prosthesis[101]. The location of the probe tip penetration around the implant found that the mean discrepancy between probe penetration and location of bone margin was 1.17 mm after 1 year of loading[102]. Generally, peri-implant probing depth appears more sensitive to force variation during probing than for similar measurements around teeth[102].

2.10 Forces and peri-implant bone

Biting forces are greater in posterior area compared to anterior areas[103]. This results in increased forces transmitted to the peri-implant bone which can have different effects based on the type and amount of force[103]. Some found that late failure of primarily machine surface implants was seldom related to infectious factors but rather the mixture of poor bone quality and overload was considered to be the leading cause for the late implant failure[104]. Others discussed the effect of mechanical stress resulting in strain and deformation of bone around dental implants[105]. The amount of strain was directly linked to the stresses applied to the bone and the strain was dependent on the mechanical properties of the bone like bone quantity and quality of both the cortical and cancellous bone[105].

2.10.1 Type of forces and peri-implant bone response

The concept of intrinsic capability of bone adaptation to surrounding structures and forces are described by Wolff's Law[53]. Some studies described that the response of peri-implant bone to increased mechanical stresses below a certain threshold, results in strengthening of the bone by increasing bone density or apposition[105]. Nevertheless, fatigue micro damage results in bone resorption as a result from mechanical stresses beyond this threshold[106]. Later on, the same author stated that there are four types of strain on bone[107]. Firstly, if no stress or force is placed on bone, disuse bone resorption may appear[107]. Secondly, if the load is physiologic then bone homeostasis occurs[107]. Thirdly, mild overload results in bone mass increase while pathologic overloading results in bone damage, and subsequent fracturing[107]. Several studies confirmed this by showing increased bone density surrounding mechanically loaded implants compared to non-loaded implants in monkeys[108,109].

2.10.2 Excessive force and implant response

A series of studies were conducted to evaluate the effect of occlusal overload on peri-implant tissue in animal models and confirmed the occurrence of excessive crestal bone loss[110,111]. High premature contacts of various amounts on implants placed in monkeys found that the higher the premature contact the more crestal bone loss even with only 4 weeks of loading[110,111]. Bone loss was found when the occlusal contact was high by 180um and 250um[110,111].

Another series of studies was conducted in monkeys to evaluate the effect of supra occlusal contact[22,105,112,113,114]. Five implants placed in the mandible of four monkeys and restored by two implants in a supra occlusal contact with lateral displacement while, the other three implants had a cotton cord placed around to increase plaque accumulation[22,105,112,113,114]. Furthermore, the supra occlusal implants were cleaned and the others were not. They found that five of eight implants with excessive occlusal loads were lost in 4.5 to 15.5 months of overloading on the other hand none of the implants with plaque accumulation were lost after 18 months yet there was 1.8mm crestal bone loss[22,105,112,113,114]. On the other hand, conflicting results using dog model, showed plaque accumulation caused progressive bone loss around implants in monkeys and dogs[115]. The five implants that were lost due to excessive loading had a different peri-implant radiolucency pattern whereas the implants that were in supra occlusion and had mucosal health and the investigators found no effect of high occlusion on the crestal bone loss[115]. The main difference in these studies was type of animal, amount of bone mineralization near the implant and direction of load. Heitz-Mayfield et al, (2004) studied implants that were loaded axially and Isidor used adverse lateral loading. Others subjected unloaded implants and loaded implants with 300N maximum and 10N minimum for 500 cycles per day for five consecutive days found after loading there was significant crestal bone loss in loaded versus unloaded implants[115].

However, other investigators argued that there is a positive relationship between occlusal trauma and peri-implant bone loss[20]. They considered that bone remodeling that happens at cellular level is controlled by the mechanical environment of stain[20]. One of the major causes of occlusal overloading is parafunctional habits, and several studies here linked it to late implant failure[116,117]. Others reported that implants are more likely to fail when they support a posterior single tooth or removable partial dentures rather than over dentures or complete fixed prosthesis[118]. Others reported excessive marginal bone loss and implant loss in patients lacking anterior contacts, presence of parafunctional habits and full fixed implants supported prosthesis in both jaws[1,119]. However, one study evaluated the effect of occlusal wear as a probable sign of bruxism on bone loss and implant stability and found no significant impact on the rate of annual vertical bone loss [120].

2.10.3 Clinical recommendation to prevent implant overloading

According to the evidence available in the literature, there are numerous factors contributing to implant overload. Possible overloading factors include cantilevers greater than 15mm in length in the mandible or more than 10 to 12mm in the maxilla, parafunctional habits, excessive premature contacts, large occlusal table, steep cusp inclination, poor bone density and quality, and insufficient number of implants to support a large prosthesis[14,121]. Additionally, several methods to reduce the potential overload are recommended such as a passive fit of the prosthesis, reducing cantilever length, narrowing the bucco-lingual and mesio-distal dimension, reducing cusp inclination, bruxism appliances, eliminating excursive contacts and centering occlusal contacts[14,121].

2.10.4 The different response between implants and teeth in relation to force

Implants and teeth behave and react to forces differently. Natural teeth when subjected to a lateral load tend to rotate around a center of rotation which is typically located in the apical third of the root and forces are dissipated from the crest of the bone along the root[122]. In contrast, implants lack a periodontal ligament and when subjected to lateral load the forces concentrate at the crest of the surrounding bone with no rotation[122].

2.11 Biological and technical complications of single implant-supported prostheses versus implant-supported fixed prostheses

Implant complications are categorized into two groups which are technical complications and biological complications. These complications will be discussed in greater detail in the following sections. First, biological complications are defined as those that are associated with the implant placement and the healing of the surrounding structures. Second, technical complications are defined as those associated with the prosthetic component of the implant or the protheses itself[6,7].

Technical complications are classified as implant fracture, loss of supra structure, abutment fracture, veneer or framework fracture, esthetic and phonetic problems, abutment loosening, loss of retention, loss of screw hole sealing, and occlusal adjustment[123].

Lee et al, (2016) compared the complications of splinting two implant prostheses and single implant restorations over a period of 40 months in a total of 234 patients with 408 implants and reported that the mechanical complication rates were lower in splinted implant prostheses, while the biological complication rates were higher in splinted implant prostheses[19].

2.11.1 Biological complications of single implant-supported prostheses versus implant-supported fixed prostheses

In this section three main biological complication will be discussed as follows: access to hygiene procedures, occlusion and bone loss.

2.11.2 Access to hygiene procedures

It has been mentioned previously that one of the advantages in single implant-supported prostheses is mainly to maintain good hygiene access by the patient especially in the interproximal areas[124].

Yet it is vital to understand that a well-designed implant-supported fixed prosthesis should provide an adequate access for oral hygiene, which helps in avoiding peri-implantitis[124].

Assessment of peri-implantitis around 109 implants, concluded that 48% of patients without adequate access for oral hygiene had peri-implantitis and only 4% of patients with proper access for oral hygiene had peri-implantitis[125]. Still, it is important to highlight that most of the patients had relatively good plaque control around their natural teeth but not at implant sites[125]. Others found that the median full mouth plaque score of 2 was correlated with peri-implantitis with odds ratio of 14[126]. The findings agree with other studies that there is substantial evidence that poor oral hygiene is linked with peri-implantitis[125,126]. The number of implants and the prevalence of peri-implantitis was evaluated in a total of 161 implants grouped into two groups those that had 5 implants or less and those that had more than 5 implants[172]. In the group with 5 and less implants 20.43% had peri-implantitis whereas 38.24% of the group with more than 5 implants had peri-implantitis[127]. Hence, there is an increased risk of peri-implantitis with more than 5 implants[127]. Moreover, other literature reported that having more training and experience can improve prosthesis design which in turn results in less implant complications[128]. Therefore, oral hygiene procedures are easier in non-splinted implant cases compared to splinted implants where extra care must be implemented regarding implant position and prosthesis design.

2.11.3 Occlusion

Due to the biophysiological differences between natural teeth and dental implants, studying the role of occlusion is challenging as it is unethical to study occlusal overload in human subjects, hence most of the literature relies on in-vitro or animal studies. Furthermore, with literature on this topic, the exact role of occlusion in dental implantology is still controversial[105,129]. For example, in 1996, Isidor found a negative association between excessive occlusal load on implants leading to loss of osseointegration[22]. Conversely, Berglundh et al, (2005) found a positive association where it was suggested that functional load on implants may enhance osseointegration and does not result in marginal bone loss[130]. Heitz-Mayfield et al, (2004) found no association after a period of 8 months of excessive occlusal load on implants did not show loss of osseointegration or marginal bone loss in compression with non-loaded implants[115]. A systematic review by Sheridan et al, (2016) investigated occlusion on dental implants, its impact on the surrounding peri-implant tissues, and the effects of occlusal overload on implants[131]. They found that the literature is lacking evidence for implant occlusion and it should be carefully assessed [131]. They also recommended a mutually protected occlusion with anterior guidance and evenly distributed contacts with freedom in centric relation for single or fixed partial denture[131], as well as reducing occlusal overload on implants by minimizing the number of cantilevers, increasing the number of implants, narrowing the occlusal table, decreasing cuspal inclination, and monitoring parafunctional habits[131].

Hypermobility of teeth is a consequence following the loss of tooth supporting structures due to periodontitis and high occlusal forces. Therefore, the concept of splinting natural teeth was based on helping to protect against traumatic or high occlusal loads[132]. Some authors hypothesized that implant-supported fixed prostheses would help in distributing occlusal forces along the implants[2,17,21]. As it was stated earlier, finite element analysis showed that in implant-supported fixed prostheses there is better load distribution along the implants and less stress to the surrounding bone[90,91]. Load distribution in splinted and non-splinted prostheses in vitro found that there is better and even load distribution among splinted implant prostheses[17]. While others studied the stress generated in splinted and non-splinted implants and found that the stress level in bone surrounding splinted implants were less than the stress level in non-splinted implants by a factor of nearly[8]. Others found, however that splinting implants with length of 11 mm and 15 mm slightly improved the strain distribution but it was not statistically significant[5]. Moreover, a study performed to identify the types of complications that have been reported in implants and associated implant prostheses found that multiple splinted implants had 1% implant body fracture[73].

2.11.4 Bone loss

The amount of bone loss around single implant-supported and implant-supported fixed prostheses has been evaluated on radiographs whether panoramic or intraoral periapical radiographs[29]. Some studies suggested that implant-supported fixed prostheses have helped to limit crestal bone loss particularly in special cases such as narrow implant diameters[29] or short dental implants[4]. More crestal bone loss is expected around implant-supported fixed prostheses than single implants[133]. For instance, one study examined short implants of 5mm or 7mm and long implants of 9mm or 12mm by measuring the distance from the alveolar crest to the machined surface of the implant at 1, 6 months, and yearly following the delivery of the prostheses[134]. The implant length on splinted prostheses had an effect on bone, whereby long implants had more crestal bone loss than short implants[34]. In addition, splinted implants had more crestal bone loss of 0.5 ± 0.4mm compared to 0.3 ± 0.4mm loss in non-splinted, but this is not clinically significant[134]. Others confirmed these results by examining a total of 192 implants placed in the posterior region and measuring the distance from the implant shoulder to the first visible bone to implant contact with the use of intraoral periapical radiographs after one year of implant placement and then every two years[135]. They reported annual bone loss in splinted implants was 0.05 ± 0.19mm versus 0.01 ± 0.25mm in non-splinted implants yet there was no statistical significant difference[135].

Others compared marginal bone level changes of adjacent splinted implants versus non-splinted implants functionally loaded with cemented restorations up to five years[35]. They measured the distance between apical end of the smooth collar of the implant and bone crest at 4 months and annually for 5 years using intraoral radiographs and found there was bone loss of 0.7 ± 0.2mm in splinted implants versus 0.8 ± 0.2mm in non-splinted implants but this was not statistically significant[35]. On the other hand, in the follow up study they evaluated marginal bone loss at 10 years and found the mean bone loss was 1.2 ± 0.2mm in implant-supported fixed prostheses and 1.3 ± 0.3mm in single implants which was statistically significant yet it is only 0.1mm difference which is not clinically significant[8].

Furthermore, Wagenberg et al, (2013) evaluated the retention of bone around implants placed immediately following extraction using intra-oral periapical radiographs at 1 to 22 years of loading[136]. They measured the distance between the most coronal implant thread to the alveolar crest and reported 0.44 ± 0.68mm of bone loss for single implants versus 0.55 ± 0.85mm for splinted implants yet it was not statistically significant[136]. On the other hand, Wagenberg et al, (2015) measured the distance between the top of the first thread and the bone crest using intra-oral periapical radiographs on rough surface anodic oxidized surface implants and reported a mean bone loss of 0.3 ± 0.65mm for single implant and 0.5 ± 0.8mm for splinted implants which was statistically significant yet not clinically significant[137]. Other experts measured the distance between the platform and the first bone to implant contact using intra-oral periapical radiographs and found no statistical significant between splinted and non-splinted implants in bone loss in relation to both the implant length and the implant position whether in maxilla or in mandible[138].

Other studies evaluated the amount of bone gain around sand blasted fluoride modified implants via measuring the distance between the bottom of the machined level and the bone crest using intra-oral periapical radiographs on the day of prostheses fitting and annually for 3 years[4]. They reported no significant difference at 1, 2, or 3 years between implant-supported fixed prostheses and single implant-supported prostheses, however, they found significant difference between both in short implants (6mm). In addition, they reported a gain in mean bone level of 0.41mm for single implant-supported prostheses at 24 months and 0.37mm at 36 months[4]. Hence, there is no difference in marginal bone loss between implant-supported fixed prostheses and single implant-supported prostheses.

2.11.5 Technical complications of single implant-supported prostheses versus implant-supported fixed prostheses

In this section the main technical complications will be discussed as follows: poor fit of prosthetic components, porcelain chipping, screw loosening and crown de-cementation.

Pjetursson et al, (2004) classified the technical complications into major, medium, and minor complications[139]. The major technical complications included implant fracture and loss of superstructure, while medium technical complications included abutment fracture, esthetic and phonetic complications[139]. Finally, the minor technical complications included abutment and screw loosening, loss of retention, loss of screw hole sealing, veneer chipping, and occlusal adjustment[139].

One of the success criteria of an implant is marginal bone stability but this alone is insufficient, therefore success of a particular treatment is best described as lack of complications after loading. A systematic review, to assess 5 and 10-year survival of implant-supported fixed dental prostheses, reported that implant success without any complication was no more than 66.4%[140]. Additionally, most of the complications were technical complications including 13.5% fractures of the veneering material, 8.5% peri-implantitis and soft tissue complications, 5.4% loss of access whole restoration, 5.3% abutment or screw loosening, and 4.7% loss of retention of cemented fixed dental prostheses[140].

The literature suggests that technical complications are more common in splinted implants prostheses in comparison to single implant prostheses due to the complexity of fabricating and delivering multiple adjacent prostheses[29].

2.11.6 Poor fit of prosthetic components

As discussed earlier, biological complications include loss of osseointegration[142], pain[142], plaque accumulation around implants[143] and marginal bone loss[144]. Technical complications, on the other hand, include fracture of implant itself and any of its components[145], loosening of the abutment and chipping or fracture of the veneering porcelain of the prostheses[146].

New 3-dimensional imaging with the aid of optical impressions could substantially reduce the poor fit resulting from analogue impression errors[147]. Ultimately, the supra-structure design whether splinted or non-splinted will affect the passive seating and fitting of the prosthesis.

2.11.7 Porcelain chipping, screw loosening and crown de-cementation

The most common prosthetic complication in the single dental implant prosthesis was screw loosening whereas the most common prosthetic complication in splinted dental implants was crown fracture while repeated screw loosening was not reported[19]. On the other hand, others looked for technical and biological complications between single crowns and bridges (fixed partial dentures) on implants over a period of 10 years and found that 31% of implant-supported fixed prostheses had prosthetic complications such as screw loosening and loss of retention whereas for single implant-supported prostheses 7.1% had screw loosening and 5.4% had loss of retention[148].

A 10-year randomized controlled trial evaluating the marginal bone changes around multiple adjacent dental implants restored with implant-supported fixed prostheses versus single implant-supported prostheses found no biological complication such as peri-implantitis, no prosthetic complications such as loosening of abutment or crown, fracture of porcelain, and loosing of temporary cemented definitive crown[8,35]. Clelland et al, (2016) compared the incidence of complications in splinted versus non-splinted implants in a split mouth clinical prospective study and found that screw loosening complications occurred only in non-splinted implant prostheses[4]. Similarly, short dental implants in the posterior region are associated with higher loading forces, poor bone quality, and poor crown root ratio which can lead to higher failure rates[70,149]. Likewise, former studies showed that using short dental implants with single crowns in the posterior region with high masticatory forces increases the risk of micro motion beyond the physiological limits and leads to marginal bone loss[85]. Moreover, it is evident in the literature that a crown height of 12mm will have double the amount of stress compared with a crown height of 6 mm and it would create uneven stress distribution thus leading to screw loosening, screw fracture, and later implant failure[150]. Thus, Yilmaz et al, (2011) and others supported that implant-supported fixed prostheses provide even stress and strain distribution within bone and avoid overload and bone loss[2,17]. Ceramic fracture in implant-supported fixed prostheses was reported to be 8.8% and in single implant-supported prostheses was 3.5%[140].

A systematic review of the prosthetic complications of implant supported bridge (fixed partial dentures) after an observation period of 5 to 10 years found that 38.7% of all implant supported fixed prosthesis have some type of complication within 5 years[140]. They also reported that the overall success rate of the prosthesis was 96.05%, with no cases of screw loosening or supra structure fracture but porcelain fracture occurred in 3.95%[140]. They also found that prosthetic complications were more common in implant-supported fixed prostheses which had a success rate of 94.4% while single crowns had a success rate of 98.4%[140]. Furthermore, Berglundh's review in 2002 claimed that every 4th patient had a component and supra structure complication over the 5 years of function[151]. On the other hand, for full arch fixed complete dentures, every 2nd patient had a supra structure complications and every 5th patient had a component complication over the 5 years of function[151].

The survival rate of implants after 5 years is 95% and reduces to 86.7% after 10 years[123]. Success rate of single implant was reported to be 94.3% whereas implant-supported fixed prostheses was 97.1% which was not statistically significant[152]. Additionally, it was found that the success rate for short dental implants in implant-supported fixed prostheses is 97.7% and in single implant-supported prostheses is 93.2% but both had similar bone loss[149]. However, others stated that using long dental implants either implant-supported fixed prostheses or single implant-supported prostheses has similar survival rates and similar marginal bone loss[26,27].

2.12 Clinical recommendations to prevent technical and biological complications

In order to reduce the risk of complications, it is important to choose restorations that will facilitate a passive fit yet clinically this might be challenging especially multiple adjacent implants. In those cases, it is advisable that one avoid splinting if possible as achieving a passive fit for screw retained prostheses is more difficult for both laboratory technician and the clinician[153]. Furthermore, modifying the interproximal contacts to allow the passive seating of the individual prostheses whether it is screw retained or cemented is crucial[153].

Ravida et al, (2017), recommended avoidance of splinting implant prostheses in patients with decreased manual dexterity, poor oral hygiene, and three or more adjacent implants[6]. The authors advocated splinting implant prostheses in patients with a history of bruxism, weak bone, heavy load area, narrow diameter implants, and short implants[6]. Hence, it is the responsibility of the clinician to assess the risks and the benefits of either implant-supported fixed prostheses or single implant-supported prostheses based on the expectations and compliance of the patient, the position of the implants, gaps, and the length of the gaps. Technical complication includes the ability to fabricate the prostheses individually might not be feasible, thus splinting the prostheses may be required.

3. AIM

This study aimed to assess the clinical outcomes of single implant-supported prostheses and implant-supported fixed prostheses in Al Badaa Dental Center in Dubai Health Authority (DHA).

4. MATERIALS AND METHODS

4.1 Objectives of the study

1- To identify the biological complications of single implant-supported prostheses and implant-supported fixed prostheses and in particular crestal bone loss.

2- To identify the prosthetic complications of single implant-supported prostheses and implant-supported fixed prostheses.

3- To compare the biological and prosthetic complications of single implant-supported prostheses and implant-supported fixed prostheses.

4.2 Research ethics board approval

Approval for the study was obtained from the Research and Ethics Committee at Hamdan Bin Mohammed Collage of Dental Medicine (Reference number: 0917-001) (Appendix 1), University Student Research Evaluation Committee in Dubai Health Authority (Reference number: USREC03-10/PG/2018) (Appendix 2) and Dubai Scientific Research Ethics committee in Dubai Health Authority (Reference number: DSREC-SR-03/2018_04) (Appendix 3).

4.3 Hypothesis of the study

The null hypothesis is that single implant-supported prostheses and implant-supported fixed prostheses have no difference in bone loss and have no difference in biological and prosthetic complications.

4.4 Study design

This retrospective study planned to compare the clinical outcomes, biological and technical complications among single implant-supported prostheses and implant-supported fixed prostheses in Al Badaa Dental Center in Dubai Health Authority (DHA). The sample size is based on a time framed sample of all patients who received dental implant treatment in the center between the period of January 2009 to December 2016.

4.5 Inclusion criteria

1- All cases where a single implant-supported prostheses were placed in the anterior and/or posterior region.

2- All cases where an implant-supported fixed prostheses were placed in the anterior and/or posterior region.

3- All implant prostheses have to be in function for at least 1 year and with a recall intra-oral periapical radiograph of sufficient quality to assess crestal bone levels.

4.6 Exclusion criteria

1- Cantilevered implants.

2- Implants supporting complete dentures.

3- Implants supporting removal partial dentures.

4- Any implant site that received bone graft material.

5- Any case involving a sinus lift procedure.

4.7 Surgical and prosthetic procedures

Implant procedures were performed according to implant manufacturers guidelines either in the oral surgery department or periodontology department in Dubai Health authority (DHA). Implant prostheses were fabricated in the prosthodontic laboratory of Dubai Health Authority (DHA).

4.8 Data collection

Data was collected from patient's electronic records in Dubai Health Authority (DHA) using the dental practice management software (D4W) and entered into International Business Machines Statistical Package for Social Sciences (IBM-SPSS) for Windows version 23.0 (SPSS Inc., Chicago, IL). Data collection form was divided into three main categories: patient demographics, implant information, prosthetic information, biological complications and technical complications (Appendix 4).

Patient demographics included gender, age, medical history, patients' habits such as smoking and parafunctional habits and number of remaining teeth excluding the third molars. Implant information included implant manufacture type, position, dimensions, time of insertion, time of loading and age of the implant. Prosthetic information included type of prostheses either single implant-supported prostheses and implant-supported fixed prostheses and type of anchorage.

Biological complications included bone height mesially and distally, periapical radiolucency, implant mobility, peri-implantitis, and implant removal. Prosthetic complications included screw loosening, screw fracture, ceramic chipping, de-cementation of implant crown and re-make the prostheses.

4.9 Radiographic analysis

Digital radiographs were analyzed for crestal bone level with the aid of software (Digora digital intraoral imaging) to produce millimetric measurements. Bone height was measured and analyzed by the study investigator who was not involved in the patient's treatment. An Intra-examiner correlation co-efficient (ICC) was calculated to determine the correlation between first and second reading in measuring crestal bone loss on digitalized periapical films.

Two intra-oral peri-apical radiographs were obtained from each patient's electronic file. The first radiograph was taken at the time of prosthetic restoration insertion as a baseline measurement of crestal bone levels on both mesial and distal sides. The second radiograph was taken at least one-year post prosthesis insertion. A sample set of radiographs where examined by the author and Intraclass Correlation Coefficients (ICC) performed. Thereafter, the author analyzed the entire sample of radiographs for crestal bone levels on mesial and distal sides from the implant abutment interface to the most apical area of bone implant contact and the difference was calculated as crestal bone loss and was entered in the database.

4.10 Statistical analysis

Data were entered in the computer using International Business Machines Statistical Package for Social Sciences (IBM-SPSS) for Windows version 23.0 (SPSS Inc., Chicago, IL). An intra-examiner reliability kappa was calculated to determine the correlation between the first reading and second reading in measuring crestal bone loss on digitalized intra-oral periapical radiographs.

Categorical variables were described by using proportion and continuous variables were described by a measure of tendency and measure of dispersion. Categorical variables were cross-tabulated to examine the independence between variables, for such variables the Chi square test or Fisher's exact test as appropriate were used. Kolmogorov-Smirnov was used to test the normality of continuous variables like bone loss on mesial and distal surfaces. The Mann-Whitney test was used to compare the means of bone loss between the two groups. When comparing the means between more than two groups the Kruskal-Wallis test was used. A p-value of less than 0.05 was considered significant in all statistical analysis.

5. RESULTS

A set of 10 intra-oral periapical radiographs were measured by one examiner and the Intraclass Correlation Coefficients (ICC) calculated. The ICC was 0.84 which is considered highly reliable. Patients' electronic records in Dubai Health Authority (DHA) were examined with the help of dental practice management software (D4W) for information regarding dental implant procedures done between January 2009 to December 2016. A total of 455 patients met the inclusion criteria, with gender distribution as follows: 64% females and 36% males. Table 1 shows that males had a mean age of 53.7 years which was significantly greater than the mean age of females at 49.3 years ($p < 0.001$). The characteristics of the study sample are shown in Table 2.

Table 1- Age of the participants by gender

	Gender	**N**	**Mean**	**Std. Deviation**
Age	Females	304	49.3	12.9
	Males	151	53.7	14.6

Table 2- Characteristics of study sample

Characteristics	**Frequency**	**Percent**
Medically fit	290	64%
Medical condition present	165	36%
Non-smoker	404	88.8%
Smoker	51	11.2%
Non-bruxist	414	91%
Bruxist	41	9%

A total of 1673 implants were placed in the 455 cases who met the inclusion criteria. The age of the implant was defined in this study as the time from implant placement until the time data collection was finished (August 1st, 2018). Mean implant age was 4.80 years (Range 1– 9.75 years) and the mean time for implant loading was 8.80 months (Range 1 – 25 months).

Table 3- Implant and operator data

		Frequency	Percent
Case type by implant	Single implant-supported prostheses	780	46.6%
	Implant-supported fixed prostheses	893	53.4%
Implant anchorage	Screw type	1607	96.1%
	Cement type	66	3.9%
Implant manufacture type	Astra	51	3%
	Xive	485	29%
	Ankylos	1125	67.2%
	Frialit	12	0.7%
Operator by patient	Maxillofacial	217	48%
	Restorative (periodontist and prosthodontist)	238	52%

Implants were grouped into two categories as either single implant-supported prostheses or implant-supported fixed prostheses but it should be noted that 111 cases had a mixture of both. While implant anchorage was divided into screw or cement type (Table 3). A total of 743 of single implant-supported prostheses were screw retained while 37 were cement retained. While, a total of 864 of implant-supported fixed prostheses were screw retained and 29 were cement retained. Depending on the preference of the operator four different implant manufacturers were included in the study (Table 3).

Table 4- Position of implant in the oral cavity

Implant position	**Frequency**	**Percent**
Upper right posterior sextant	347	20.7%
Upper anterior sextant	176	10.5%
Upper left posterior sextant	277	16.6%
Lower left posterior sextant	389	23.3%

Lower anterior sextant	92	5.5%
Lower right posterior sextant	392	23.4%
Total	1673	100%

Table 4 shows the implant position in the oral cavity. The most frequent sites for implant placement were the lower left and right posterior sextants while the least common site was the lower anterior sextant.

Table 5- Frequency distribution of implant type by operator preference

		Operator	
		Maxillofacial	**Restorative**
Implant manufacture type	**Astra**	9 (1.1%)	42 (5.1%)
	Xive	100 (11.7%)	385 (47%)
	Ankylos	742 (86.9%)	383 (46.8%)
	Frialit	3 (0.4%)	9 (1.1%)
Total		854 (100%)	819 (100%)

Table 5 shows the distribution of implant type according to operator preference. Ankylos was the most preferred implant type used by 86.9% maxillofacial surgeons compared to 46.8% of restorative operators (p<0.001). On the other hand, Xive was the most preferred implant used by 47% of restorative operators compared to 11.7% of maxillofacial surgeons.

Table 6- Mean crestal bone loss by study variables

Study variables	**Mean crestal bone loss mesially (SD), mm**	**P value**	**Mean crestal bone loss distally (SD), mm**	**P value**
Gender Male (n=304) Female (n=151)	 0.78 (0.73) 0.72 (0.66)	 NSS	 0.93 (0.85) 0.82 (0.75)	 <0.001*

Age				
20 – 40 (n=123)	0.63 (0.72)	<0.001*	0.74 (0.85)	<0.001*
41 – 60 (n=200)	0.68 (0.64)		0.80 (0.77)	
61 – 100 (n=132)	0.89 (0.70)		0.99 (0.75)	
Case type				
Single implant-supported (n=780)	0.30 (0.43)	<0.001*	0.36 (0.54)	<0.001*
Implant- supported fixed (n=893)	1.14 (0.63)		1.29 (0.71)	
Medical condition				
No (n=290)	0.67 (0.66)	<0.001*	0.78 (0.77)	<0.001*
Yes (n=165)	0.86 (0.71)		0.98 (0.80)	
Smoking				
No (n=404)	0.75 (0.67)	NSS	0.87 (0.78)	NSS
Yes (n=51)	0.68 (0.79)		0.78 (0.87)	
Bruxism				
No (n=414)	0.75 (0.68)	NSS	0.87 (0.79)	<0.05*
Yes (n=41)	0.67 (0.72)		0.72 (0.73)	
Implant anchorage				
Screw type (n=1607)	0.75 (0.69)	<0.05*	0.86 (0.80)	NSS
Cement type (n=66)	0.56 (0.56)		0.77 (0.56)	
Implant position				
Upper right posterior sextant (n=347)	0.77 (0.73)	<0.001*	0.91 (0.84)	<0.001*
Upper anterior sextant (n=176)	0.70 (0.60)		0.87 (0.67)	
Upper left posterior sextant (n=277)	0.73 (0.69)		0.83 (0.78)	
Lower left posterior sextant (n=389)	0.72(0.70)		0.82 (0.83)	
Lower anterior sextant (n=92)	1.16 (0.68)		1.25 (0.80)	
Lower right sextant (n=392)	0.67 (0.64)		0.76 (0.73)	
Implant manufacture type				
Astra (n=51)	0.46 (0.50)	<0.05*	0.67 (0.51)	NSS
Xive (n=485)	0.76 (0.69)		0.88 (0.80)	
Ankylos (n=1125)	0.75 (0.69)		0.86 (0.79)	
Frialit (n=12)	0.58 (0.63)		0.83 (0.83)	

Operator				
Maxillofacial (n=217)	0.78 (0.70)	<0.05*	0.89 (0.78)	<0.05*
Restorative (n=238)	0.70 (0.68)		0.82 (0.80)	
NSS: Non-Statistically Significant				

Table 6 shows mean crestal bone loss mesially and distally according to several study variables. Males had significantly greater mean crestal bone loss distally compared to females (p<0.01) but not mesially. Patient's age was divided into three groups as follows: young (20-40 years), middle (41-60 years), and old (>60 years). Table 6 shows mean crestal bone loss mesially and distally increased significantly with age. Mean crestal bone loss in implant-supported fixed prostheses was 1.14mm mesially and 1.29mm distally which was significantly greater compared to single implant-supported prostheses.

Furthermore, comparison of crestal bone loss by medical condition, smoking, bruxism, operator, implant manufacture type, implant anchorage and implant position is also presented in Table 6. Mean crestal bone loss mesially and distally in patients with a medical condition was significantly greater compared to medically fit patients (Table 6). There was no significant difference in mean crestal bone loss mesially or distally among smokers or non-smokers. Non-bruxists had significantly greater mean crestal bone loss distally compared to bruxists (Table 6).

Screw retained prostheses had greater mesial crestal bone loss compared to cement retained prostheses but no significant difference was found distally. In relation to implant position, Table 6 shows that the lower anterior sextant has significantly greater crestal bone loss mesially and distally compared to the other sextants. Mean mesial crestal bone loss around Anklos and Xive implants was greater than around Astra and Frialit but there was no difference distally. Moreover, cases treated by maxillofacial surgeons exhibited significantly greater crestal bone loss mesially and distally compared to restorative operators.

Implant complications that were investigated in this study are implant mobility, peri-implantitis, screw loosening, screw fracture, ceramic chipping and de-cementation of implant crown. While the final outcome of the implant was divided into three categories as follows: in function, remake and implant removal. Implants 'In function' in this study were defined as an implant and prostheses in situ regardless of the presence or absence of biological or technical complications. Of the 1673 implants, 83% had no complication whereas only 17% had a complication. Furthermore, 96.1% of implants are still in function whereas 3.1% required prostheses remake and only 0.8% were obliged to be removed. The distribution of complications and final outcomes is listed in Table 7. While, Table 8 shows the distribution of implant complication by case type either single implant-supported prostheses or implant-supported fixed prostheses.

Table 7- Distribution of implant complications and final outcomes

		Frequency	**Percent**
No complications		1389	83%
Complications	Implant mobility	6	0.4%
	Peri-implantitis	9	0.5%
	Screw loosening	193	11.5%
	Screw fracture	12	0.7%
	Ceramic chipping	19	1.1%
	Crown de-cementation	45	2.7%
Final outcome	In function	1608	96.1%
	Remake prostheses	52	3.1%
	Removal of implant	13	0.8%

Table 8- Distribution of implant complications by case type

		Single implant-supported prostheses	Implant-supported fixed prostheses
No complications		673 (86.3%)	716 (80.2%)
Complications	Implant mobility	4 (0.5%)	2 (0.2%)
	Peri-implantitis	0 (0%)	9 (1%)
	Screw loosening	72 (9.2%)	121 (13.5%)
	Screw fracture	3 (0.4%)	9 (1%)
	Ceramic chipping	10 (1.3%)	9 (1%)
	Crown de-cementation	18 (2.3%)	27 (3%)

Table 9 shows frequency of implant complications by gender, age, medical condition, smoking, bruxism, operator, implant manufacture type, implant anchorage and implant position. Males have significantly more than expected implant complications compared to females. While implant complications by age were not significantly different.

Also, Table 9 shows that significantly more implant-supported fixed prostheses have complications (n=177) compared to single implant-supported prostheses (n=107). Medically unfit patients (conditions) have significantly more implant complications than expected compared to medically fit patients (Table 9). While bruxism, implant position, implant manufacture type, operator had no significant difference on implant complications. Cement retained prostheses have significantly more than expected implant complications compared to screw retained prostheses (Table 9).

Table 9- Frequency of implant complications by study variables

Study variable	No complication	Complication	P value
Gender			
Male (n=304)	489	120	<0.05*
Female (n=151)	900	164	
Age			
20 – 40 (n=123)	277	55	
41 – 60 (n=200)	620	131	NSS
61 – 100 (n=132)	492	98	
Case type			
Single implant-supported (n=780)	673	107	<0.001*
Implant- supported fixed (n=893)	716	177	
Medical condition			
No (n=290)	880	158	<0.05*
Yes (n=165)	509	126	
Smoking			
No (n=404)	1221	260	NSS
Yes (n=51)	168	24	
Bruxism			
No (n=414)	1282	265	NSS
Yes (n=41)	107	19	
Implant anchorage			
Screw type (n=1607)	1369	238	<0.001*
Cement type (n=66)	20	46	
Implant position			
Upper right posterior sextant (n=347)	292	55	
Upper anterior sextant (n=176)	134	42	
Upper left posterior sextant (n=277)	232	45	NSS
Lower left posterior sextant (n=389)	328	61	
Lower anterior sextant (n=92)	83	9	

Lower right sextant (n=392)	320	72	
Implant manufacture type			
Astra (n=51)	43	8	NSS
Xive (n=485)	418	67	
Ankylos (n=1125)	917	208	
Frialit (n=12)	11	1	
Operator			
Maxillofacial (n=217)	162	55	NSS
Restorative (n=238)	175	63	
NSS: Non-Statistically Significant			

Table 10- Distribution of any complication by case type

			Any complication		Total
			No	**Yes**	
Case type	**Single implant-supported prostheses**	Observed count	673	107	780
		Expected count	647.6	132.4	780
		% of total	40.2%	6.4%	46.6%
	Fixed implant-supported prostheses	Observed count	716	177	893
		Expected count	741.4	151.6	893
		% of total	42.8%	10.6%	53.4%
Total			1389	284	1673
$\chi 2$-square test= 11.002, P<0.001					

To understand the relationship between case type (single implant-supported fixed prostheses / fixed implant-supported prostheses) and any complication, analysis was performed by combining all types of complications into one category. Table 10 shows that two by two contingency table for this analysis by chi square. It shows that significantly more than expected fixed implant-supported prostheses had complications compared to single implant-supported prostheses.

6. DISCUSSION:

The aim of the present study was to identify and to compare the biological and prosthetic complications among single implant-supported prostheses and implant-supported fixed prostheses. The objectives were assessed through examining patients' electronic records and radiographs that were taken at routine recall appointments at Al Badaa Dental Center in Dubai Health Authority.

The present study categorized biological complications as loss of crestal bone mesially and distally, periapical radiolucency, implant mobility, and implant removal. On the other hand, the prosthetic complications were screw loosening, screw fracture, ceramic chipping, de-cementation and re-make of the implant prostheses.

The gender different behavior and attitude towards oral health in the Middle East found that females brush their teeth more and visit the dentist more often than males. Thus, it was concluded that females have superior oral health attitude and behavior than males[154,155,156,157,158]. Furthermore, Dubai Emirate had a total of 2,976,455 residents in 2017, of which 74.9% of the total population comprised of males in the working age category of 20-50 years[159]. It was reported that 65.7% of outpatients were Emirati nationals and female nationals accounted for 51.8% of the total attendance[159]. On the other hand, dental clinic attendees within primary health care are 73% female and 27% male[159]. A total of 3467 individuals had dental implant procedures in 2017[159]. Despite the higher male percentage in Dubai, it is clear that females tend to visit the dentist more frequently. Generally, it is known that females are more proactive regarding maintaining their oral health compared to males. Hence, in the present study the sample has many more female participants than males.

The pattern of tooth extraction has been assessed worldwide, however none have been conducted locally in the United Arab Emirates. Most studies indicate caries as the major reason for tooth extraction[160]. Other reasons included trauma, orthodontic reasons, prosthodontic reasons and failed endodontics[160]. The pattern of tooth extraction was evaluated at Baghdad dental teaching hospital[161] and at Islamabad medical and dental college[162] and both concluded that the mandibular first molar was the most commonly extracted tooth[161,162]. Yet the most frequent site of extraction excluding third molars in a Saudi population was the first maxillary premolar (13.2%) and then the first mandibular molar (10.9%)[163]. In the present study the most common site for implant placement was in the lower right (23.4%) and in the lower left sextant (23.3%). The reason for this is that the mandibular first molar is the first permanent tooth to erupt in the oral cavity, and more likely to become carious.

Due to the absence of consensus and a lack of randomized controlled clinical trials on which implant system is the best, clinicians tend to follow their experience in choosing an implant system[164]. An online survey to determine the criteria that influence dentist selection of implant systems concluded that 84.7% depend on the implant abutment connections, 82.8% followed the scientific evidence available on the implant system, 81.4% the simplicity of the prosthetic steps, 19.8% on patient preference[164]. Furthermore, the survey reported that the most commonly used implant surface was sandblasted large grit acid etched implant surfaces (SLA) while the least common was the fluoride coated surface[164]. Ankylos and Xive implant systems, which have large gritted acid etched implant surfaces, were the most frequently used in the present study which is corresponding to the survey results. Also, maxillofacial surgeons used Ankylos implants more frequently than restorative operators because of the simplicity of placing Ankylos implant systems as it can be placed crestal or subcrestal. While the Xive implant system needs more precision and accuracy in placing the implant as it needs to be placed crestally and if placed subcrestal then a platform switching technique is needed for the prosthetic restoration. Hence restorative operators in our study tend to use Xive more frequently as they usually restore them later on.

In the present study factors affecting crestal bone loss were assessed including gender, age, medical condition, smoking, bruxism, operator, implant manufacture type, implant anchorage, implant position and case type. According to the available literature dental implants have outstanding survival rate with long-term studies having shown 1.5 to 2mm of crestal bone loss after 1 year in function[165,166] and annually around 0.2mm after the first year[32]. In the present study implants were in function for a mean of 4.80 years with mean mesial crestal bone loss around single implant-supported prostheses of 0.30mm and distally 0.36mm, whereas mean mesial crestal bone loss in implant-supported fixed prostheses was 1.13mm and distally 1.29mm. Hence, the null hypothesis was rejected. Conversely, mean crestal bone loss did not exceed the expected crestal bone loss after the first year of function that was set by Alberktsoon et al, (1986)[32]. Thus, single implant-supported prostheses and implant-supported fixed prostheses are a viable treatment option.

Crestal bone loss was investigated between internal and external hex implants with no significant difference by gender and age[167]. While others examined the effect of age and gender and found that males tend to have higher bone loss with age[168]. A more recent study found that aging influences the biological aspect of both soft and hard tissue healing and remodeling especially after the age of 65 years[169]. In the present study males have significantly greater crestal bone loss only on the distal aspect of the implants compared to females. The reasons for this are poor access for oral hygiene on the distal aspect of the implant and forces tend to be greater as we move distally. It is well documented that biting force among males is higher than females[170]. In the present study females were significantly younger than males and it is documented that aging negatively influences crestal bone loss and manual dexterity reduces thus maintaining oral health is difficult. This accounts for crestal bone loss being greater in males and with increasing age.

Placing implants in medically compromised patients has lower survival rate and higher risk of peri-implantitis[171]. Implants can be a viable and feasible treatment option in almost any medically compromised patient but requires preventive measures and regular maintenance[172]. Even in individuals with altered bone metabolism such as osteoporotic individuals, implant survival is comparable to those seen in healthy individuals thus implant therapy is not contraindicated in osteoporosis[173,174]. The relationship of systemic conditions and crestal bone loss has been studied and a recent meta-analysis reported that the only prospective clinical trial found crestal bone loss after 10 years to be 1.5mm[175]. Conversely, others found that there is no significant relationship between crestal bone loss and systemic conditions[169], with mean crestal bone loss in patients with a medical condition of 0.96mm after 5 years[169]. In the present study individuals with a medical condition had significantly greater crestal bone loss compared to medically fit individuals. The reason behind this is due to the inter-relationship between body and oral cavity, for example diabetes and periodontal diseases are bidirectional with pro-inflammatory cytokines giving an increased risk of crestal bone loss around implants. Medications taken by patients have adverse effects on the blood circulation, wound healing and bone remodeling.

The effect of smoking on crestal bone loss was evaluated around 4591 implants followed up for 5 to 10 years[176]. Heavy smoking (more than 15 cigarettes per day) had no initial effect on crestal bone loss but there was significant bone loss after 4 years[176]. On the other hand, Calvo-Guirado et al, (2016) reported that smoking has no negative influence on crestal bone loss after a 5 year follow up[177]. Others found that the effect of smoking is still controversial on implant survival and is not a contraindication for implant therapy[178]. Smoking, especially water pipes, in the Middle East has increased by 200% in females and 60% in males[179]. The prevalence of smoking among females in Saudi Arabia found that 13.3% tried to smoke and 0.9% were active smokers and concluded that participants who tried to smoke in the past may be considered as a risk factor of becoming regular smokers in the future[180]. In the present study the effect of smoking on crestal bone loss found no significant difference between smokers and non-smokers. This can be explained by the low numbers of smokers in the present study. Furthermore, there are more female participants in the present study and some probably failed to mention their smoking habits due to cultural reasons as it is considered shameful within the Middle East.

Bragger et al, (2005) demonstrated that bruxism causes fracture of the implant supra-structure but failed to show its relation with implant failure[148]. Furthermore, Engel et al, (2001) showed that bruxism does not affect crestal bone loss[120]. Others found that overloading the implant in the absence of peri-implant inflammation causes no further crestal bone destruction whereas overloading the implant with the presence of peri-implant inflammation causes crestal bone destruction[181]. While, Esposito et al, (1998) suggested that bruxism can lead to overload of the implant which contributes to crestal bone loss[182]. The role of occlusion on dental implants is controversial although there is evidence that overload of the implant leads to bone loss[183]. The present study found a significant difference only on the distal aspect of the implant with greater crestal bone loss in non-bruxists compared to bruxists. The reasons for this are unclear and are difficult to explain due to the multifactorial etiology of crestal bone loss. Luo et al, (2019) reported that the occlusion on implant crowns changes and increases over time due to the supra eruption of the antagonist teeth[184]. Thus, implant overloading could occur without the knowledge of the clinician. Moreover, bruxist individuals are provided with occlusal protective splints.

Operator skill and experience is linked to the success rate of implants, however there is controversy within this subject[185]. Melo et al, (2006) failed to find a significant difference in implant survival among maxillofacial residents at different stages of training[186]. Whereas, Chrcanovic et al, (2017) reported that surgeon experience and skills influence the success rate of implants as the more experienced surgeons had better survival rate[186]. Nonetheless, in the present study the results showed that crestal bone loss is significantly greater in maxillofacial surgeons compared to restorative operators. The reasons for this are that maxillofacial surgeons are assigned to more complicated cases while restorative operators carefully select and plan cases taking the final prosthesis into their consideration.

According to the available literature there is lack of comparative studies assessing crestal bone loss across different implant manufacture type. Our results showed implant manufacturer type significantly influences crestal bone loss only on the mesial surface of the implant. The results showed that Ankylos and Xive had greater crestal bone loss compared to Astra and Frialit. The reasons for this are unclear due to the fact that etiology of crestal bone loss is multifactorial in origin and include unfavorable stress distribution, surgical trauma, implant-abutment micro-gap, and remodeling of the biologic width[187,188]. In addition, there are far more Ankylos and Xive implants whereas we had few Astra and Frialit implants. Furthermore, the loss of inter-proximal contact occurs frequently and continuously over time mainly after 3 months post-delivery of the restoration due to mesial drift of the natural teeth hence, inter-proximal gap develops adjacent to implant restoration[190,191,192]. Over a 13 year follow up period, contact was lost on almost 75% of restorations with the occurrence of food impaction and plaque accumulation leading to peri-implantitis and crestal bone loss[192].

The association between screw or cement retained implant anchorage on crestal bone loss was investigated, as it is known that cement retained prostheses are considered a potential risk for peri-implantitis[193]. Others showed no significant difference in crestal bone loss between screw or cement retained prostheses[167,169]. The present study agrees with Lemos et al, (2016), and Hameed et al, (2018) that screw retained prostheses show significantly greater crestal bone loss than cement retained[194,195]. The reasons for this are that the position of the access opening in a screw retained restoration, if not properly planned and designed, can lead to non-axial loading on the implant that results in crestal bone loss.

The position of the implant within the alveolar ridge and bone density also affects crestal bone loss. According to the literature, implants in the anterior maxilla have significantly less crestal bone loss compared to the posterior maxilla[169]. Others found that crestal bone loss is significantly higher in the maxillary jaw compared to the mandibular jaw[168]. On the other hand, the present study agrees with Ajanović et al, (2015), who reported that the anterior mandible has the highest crestal bone loss[196]. The reason behind this is that the speed and direction of alveolar bone resorption is not equal between maxilla and mandible, because the anterior mandible resorbs four time faster than the maxilla[197]. Another reason is that the anterior part of the mandible is mainly cortical bone and has less cancellous bone, thus it is harder to drill and operators require more force to drill, leading to excessive heat generation and crestal bone loss[40].

Crestal bone loss in single implant-supported prostheses and implant-supported fixed prostheses is still controversial due to its multiple etiology. Multiple studies showed no significant difference in crestal bone loss among single implant-supported prostheses and implant-supported fixed prostheses[8,29,35,198]. The present study is in line with others where it was reported that implant-supported fixed prostheses result in greater bone loss compared to single implant-supported prostheses[18,19,32,36,137]. The results presented here find that implant-supported fixed prostheses have significantly greater crestal bone loss mesial and distal to the implant (mesially 0.83mm and distally 0.93mm) compared to single implant-supported prostheses. The reasons for this are not fully clear but flossing and inter-proximal hygiene is difficult in the implant-supported fixed prostheses[3,13,149]. The inter-proximal and pontic areas in implant-supported fixed prostheses act as a food trap, increasing plaque and bacterial accumulation. Thus, the use of adjunctive inter-proximal hygiene aids is required to keep the area clean with regular professional hygiene follow ups. Lindhe et al, (2008) stated that plaque and bacterial accumulation results in peri-implant mucositis that progresses to peri-implantitis and crestal bone loss[24]. Furthermore, the difficulty in achieving a passive framework fit in restoring multiple implants with an implant-supported fixed prostheses[18], increases stress and strain around the implants that results in further bone loss. Occlusal overloading such as parafunctional habits result in greater crestal bone loss[1,40,41,42]. Both hard and soft tissue dimensions of the alveolar ridge are significantly reduced post extraction[199]. Furthermore, the present study found that there was less bone loss when the implant was placed adjacent to a natural tooth such as in non-splinted implants. While there was an increased bone loss when multiple implants were adjacent to each other. The reasons behind this is that the natural teeth will help in maintaining the alveolar ridge. Whereas, multiple adjacent implants naturally have greater crestal bone loss as the alveolar ridge naturally continues to remodel and resorb. Thus, the results of the present study are in line with others that reported that the implant bone level can be stabilized and maintained when placed adjacent to natural tooth compared to another implant[34,46,200]. The present study did not measure and did not take into consideration the horizontal distance between the implant and the adjacent natural tooth or implants.

In the present study 96.1% of the implants were still in function and only 3.1% required a remake and 0.8% had to be removed. Thus, the present study shows, regardless of the implant case type whether single implant-supported prostheses and implant-supported fixed prostheses that both have good survival. The present study is in line with Pjetursson et al, (2012) who estimated the survival rate of implants supporting fixed prostheses was 95.6% after 5 years and 93.1% after 10 years[139]. And they reported that 66.4% of the patients were free from any complication while the present study showed 83% had no complications[139]. The most frequent complication that was observed in the present study was 11.5% screw loosening followed by 2.7% de-cementation of the crown. Yet Pjetursson et al, (2012) reported that 13.5% veneering material fracture was the most frequent complication followed by 5.3% screw loosening[139]. Because physical properties of veneering ceramic have evolved and improved less ceramic chipping is reported in the present study.

There is lack of evidence in the literature regarding the association between implant complications and patient factors such as age, medical condition, and habits. In the present study the age of the participants, smoking, bruxism, implant position, operator who placed the implant, and the implant manufacture type did not significantly influence implant complications. Whereas the results showed that males had significantly more implant complications than expected compared to females. The reasons were explained earlier as males have greater biting forces[170]. Furthermore, females have better oral health than males[154,155,156,157,158]. Females tend to visit the dentist more often resulting in reduction in complications.

Furthermore, the present study found that medically unfit participants had significantly more implant complications than expected. The reason for this is unclear as there is lack of evidence in the literature comparing implant complications among medically fit and unfit individuals. The prevalence of medical unfit patients seeking dental treatment in College of Dentistry, King Khalid University in Saudi Arabia was investigated and found that 10.3% had medically conditions[201]. Implant therapy requires regular follow up and professional oral maintenance program throughout the patient's life. Medically unfit individuals fail to attend to their follow up appointments, whereas medically fit patients are active towards their oral health.

The present study results showed that implant complications are higher than expected in cement retained prostheses compared to screw retained prostheses. The literature recommends screw retained prostheses due to its ease of retrievability, less biological complication such as peri-implantitis and ease of repair[32,153]. Nonetheless, the major drawback in screw retained prostheses are screw loosening, screw fracture and chipping of the ceramic hence it requires precise and meticulous surgical techniques and prosthetic designing[32,153]. Cement retained prostheses provide optimal occlusal design, superior esthetics, and passive fit of the restoration[202,203]. Yet their major drawback is the possibility of leaving excess cement that results in peri-implantitis[202,203]. Cement retained prostheses had more biological complications whereas, screw retained had more technical complications[204]. Another systematic review found no statistically significant difference between screw and cement retained prostheses but screw retained displayed fewer technical complications[205]. The reasons for this include issues related to excess cement which increases the risk of microflora colonization leading to signs of peri-mucositis and or peri-implantitis.

A recent systematic review found no statistically significant difference in prosthetic complications among single implant-supported prostheses and implant-supported fixed prostheses[206]. Whilst, others showed that most prosthetic complications among implant-supported fixed prostheses were ceramic chipping[4,207,208]. Most prosthetic complications among single implant-supported prostheses were screw loosening, ceramic chipping and loss of retention[4,207,208]. Conversely, no screw loosening and no superstructure fracture was found among implant-supported fixed prostheses and only 3.95% had ceramic fracture[140]. It has been reported that most technical complications in implant-supported fixed prostheses are fractures of the veneering material, abutment or screw loosening, and loss of retention[139]. The present study showed that 11% of implant-supported fixed prostheses had complications which is significantly higher than 6% of single implant-supported prostheses. Furthermore, the most common prosthetic complication in the present study in both single implant-supported prostheses and implant-supported fixed prostheses was screw loosening which is in line with previous studies. Conversely, Clelland et al, (2016) compared the incidence of complications in splinted versus non-splinted implants in a split mouth clinical prospective study and found that screw loosening occurred only in non-splinted implants which is not in line with the present study[4]. Increased screw loosening in the present study could be explained due to greater inter-arch distance, increased crown to implant ratio, inadequate tightening torque and stress generation that changes the screw geometry, causing metal fatigue and ultimately leading to screw loosening[209,210,211,212].

6.1 Study limitations

The design of the present study is retrospective and the data collection relied on previous chart entries by multiple clinicians that might have inherent flaws. Additional variables such as smoking status and medical conditions that affect the implant status were not reported by the patient or not updated by the dentist. The present study did not conduct clinical measurement of the peri-implant soft tissue such as the phenotype, thickness, and plaque index. Furthermore, a confounding factor that was not assessed was the periodontal status of the adjacent teeth, as these may contribute to crestal bone loss. In addition, crestal bone loss around implants occurs in a three-dimensional manner and the radiographic assessment only allow measurement of the mesial and distal surface but not the buccal and lingual.

7. CONCLUSION

The present study yielded several results that agree with other reports in the literature and also creates potential new areas for further investigation. Single implant-supported prostheses and implant-supported fixed prostheses and their effects on bone has been assessed. Within the limitation the present study concludes the following:

1- Implant-supported fixed prostheses have significantly greater crestal bone loss compared to single implant-supported prostheses.
2- Patient's age, medical condition, implant position, and operator significantly affects the crestal bone loss.
3- Gender and bruxism significantly affect crestal bone loss distally.
4- Implant-supported fixed prostheses have significantly more implant complications compared to single implant-supported prostheses.
5- Gender, patient's medical condition, type of implant anchorage have significant effect on implant complications.
6- Patient's age, smoking, bruxism, implant position, implant manufacturer and operator did not have any significant effect on implant complications.

The present study concludes that bone loss is greater on implant-supported fixed prostheses than on single implant-supported prostheses. The factors associated with this need further research. Hence, the recommendation of the present study is that whenever implant-supported fixed prostheses is a must, careful planning and careful designing of the prostheses is required.

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9. APPENDICES

9.1 Appendix 1

MBRU
جامعة محمد بن راشد للطب و العلوم الصحية
MOHAMMED BIN RASHID UNIVERSITY OF MEDICINE AND HEALTH SCIENCES

Date: 31/01/18

Dear Dr Sara Al Hammadi

Re: Your research protocol

Titled: Complications of splinted implant prosthesis versus non-splinted in DHA

Thank you for submitting your research protocol to the Research and Ethics committee of the Hamdan Bin Mohammed College of Dental Medicine, MBRU.

It was considered originally at the meeting held on 15 October 2017

Following minor revision it has now been approved.

The committee would like to remind you that it is a requirement of the programme that you complete a research dissertation, which comprises 15% of credits within the 3-year MSc programme. We wish you every success with your project.

With best wishes

Yours sincerely,

Alex Milosevic

Prof A Milosevic

Chair, Research and Ethics Committee, HBMCDM

P.O. Box: 505055 Dubai, UAE ص.ب: ٥٠٥٠٥٥ دبي، الإمارات العربية المتحدة | Location: Building 14 Dubai Healthcare City الموقع: مبنى ١٤ مدينة دبي الطبية
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9.2 Appendix 2

حكومة دبي
GOVERNMENT OF DUBAI

هيئة الصحة بدبي
DUBAI HEALTH AUTHORITY

UNIVERSITY STUDENT RESEARCH EVALUATION COMMITTEE

APPROVAL LETTER

Reference: USREC03-10/PG/2018 21 March 2018

Dear Dr. Sara Hussain Al Hammadi,

Title of Project:
"A 5 years clinical outcomes of splinted implant prosthesis versus non-splinted implant prosthesis in Dubai Health Authority Clinics."

Thank you for your request to conduct research in Dubai Health Authority. Your research Proposal has been reviewed by University Student Research Evaluation Committee, and I am pleased to inform you that your research proposal has been approved to be conducted in Dubai Health Authority.

Please note that the following standard requirements are integral part of the approval:

1. This approval will be for a period of 1 year. At the end of this period, if the project has been completed, abandoned, discontinued or not completed for any reason you are required to inform the University Students Research Evaluation Committee.
2. Please remember that you must notify the Committee via email regarding any alteration to the Project protocol.
3. Please apply for ethical approval through DSREC@dha.gov.ae. After getting your ethical committee approval, you can officially start your research and data assembly.
4. Individuals or organizations conducting research studies in the Dubai Health Authority are expected to provide a copy of the research results to the committee following the completion of the study.

We wish you every success with your studies and beyond.

لجنة اعتماد طلبات إجراء البحوث لطلبة الجامعات
University Student Research Evaluation Committee
إدارة التعليم الطبي
Medical Education Department

Yours sincerely

Dr. Mahera Abdulrahman, MD, MSc., PhD
Chair, University Students Research Evaluation Committee
Department of Medical Education - Dubai Health Authority
Email: marad@dha.gov.ae

9.3 Appendix 3

حكومة دبي
GOVERNMENT OF DUBAI

DUBAI SCIENTIFIC RESEARCH ETHICS COMMITTEE
APPROVAL LETTER

هيئة الصحة بدبي
DUBAI HEALTH AUTHORITY

From :	Dubai Scientific Research Ethics Committee (DSREC) Dubai Health Authority	**Date :**	25 MAR 2018
To :	Dr. Sara Hussain Al Hammadi, Student of Master of Science in Prosthodontics, Mohammed Bin Rashid University of Medicine and Health Sciences	**Ref :**	DSREC-SR-03/2018_04
Study Site	PHC Dental-DHA		

Subject: Approval for the research proposal, ***<u>"A 5 years clinical outcomes of splinted implant prosthesis versus non-splinted implant prosthesis in Dubai Health Authority Clinics"</u>***

Dear Dr. Sara Hussain Al Hammadi,

Thank you for submitting the above mentioned research proposal to Dubai Scientific Research Ethics Committee, DHA. The Dubai Scientific Research Ethics Committee has been organized and operates in accordance with the ICH/GCP guidelines and the committee is registered with the Office for Human Research Protection (OHRP).

Your request was discussed with Dubai Scientific Research Ethics Committee. We are pleased to advice you that the committee has granted ethical approval for the above mentioned study to be conducted in Dubai Health Authority. However, you will have to approach the Medical Director of the Hospitals to secure permission to review any hospital records and to carry out your study in the hospital.

Please note that it is DSREC's policy that the principal investigator should report to the committee of the following:

1. Anything which might warrant review of ethical approval of the project in the specified format, including:
    - any serious or unexpected adverse events and
    - unforeseen events that might affect continued ethical acceptability of the project
2. Any proposed changes to the research protocol or to the conduct of research
3. Any new information that may affect adversely the safety of the subjects
4. If the project is discontinued before the expected date of completion (reason to be specified)
5. Annual report to DSREC about the progress of the study
6. A final report of the finding on completion of the study

The approval for the study expires on **<u>25 MAR 2019</u>**. Should you wish to continue the study after this date, please submit an application for renewal together with the Annual Study site progress report <u>no later than 30 days</u> prior to the expiry date.

Page **1** of **2**

GOVERNMENT OF DUBAI

DUBAI SCIENTIFIC RESEARCH ETHICS COMMITTEE APPROVAL LETTER

هيئة الصحة بدبي
DUBAI HEALTH AUTHORITY

The DSREC wishes you every success in your research.

Yours faithfully,

on behalf

Dr. Suhail Abdulla Mohd Alrukn
Chairman
Dubai Scientific Research Ethics Committee
Dubai Health Authority

Dr. May

Dubai Scientific Research Ethics Committee
Dubai Health Authority
Dubai, UAE.

Page **2** of **2**

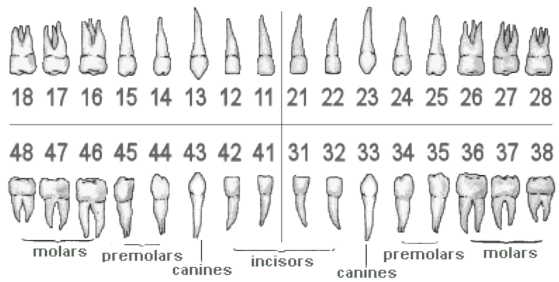
9.4 Appendix 4

<u>Data collection form</u>

- **<u>Demographic data:</u>**
    - ID No.: ……………..
    - Gender: Male / Female
    - Age: ……………. years.
    - Medical history:
        - Medically fit.
        - Medical condition present.
        - Not recorded.
    - Smoker: Yes / No
    - Bruxism: Yes / No
    - Operator who placed dental implant:
        - Maxillofacial and oral surgeon.
        - Periodontist.
        - Prosthodontist.
        - Others: ………….
- **<u>Implant details:</u>**
    - Type of dental implant:
        - Astra
        - Xive
        - Ankylos
        - Frialit

- Others: ………………

- Dental implant position:



- Length of the implant: ……… mm
- Diameter of the implant: ……. mm
- Number of remaining teeth: ………….

- **Prosthetic details:**
  - Type of supra structure design:
    - Single implant supported prostheses
    - Fixed-implant supported prostheses
  - Number of dental implants: ……………
  - Number of crowns: …………………….
  - Types of implant prosthesis anchorage:
    - Screw retained.
    - Cement retained.
  - Time of inserting the implant: ………
  - Time of implant loading: ……………
  - Age of implant: …………..
  - Date of complication occurrence: …………..

- **Dental implant complications:**

- Biological complications:
  - Bone height:
    - post prosthesis insertion:
      - mesial surface: mm
      - distal surface: mm
    - 1-year post prosthesis insertion:
      - mesial surface: mm
      - distal surface: mm
    - difference between them: mm
  - Periapical radiolucency: Yes / No
  - Mobility of the implant: Yes / No
  - Peri-implantitis: Yes / No
  - Implant removal: Yes / No
- Prosthetic complications:
  - Screw loosening: Yes / No
  - Screw fracture: Yes / No
  - Ceramic chipping: Yes / No
  - Re-make the implant prosthesis: Yes / No
  - De-cementation of implant crown: Yes / No