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Dental Implant Surgery: A Concise Review of the Literature

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ABSTRACT

Edentulism is a global challenge affecting patients' psychosocial well-being, now well-treated by dental implants. Due to the advancement in the field of oral implantology, there is a plethora of surgical techniques and protocols at the disposal of clinicians, backed by an ever-divided body of research. Treatment with dental implants has become ever more sought after because of their high survival and success rates and increased affordability. In turn, this has put increased demand on clinicians who owe their patients the highest standard of care backed by sound scientific evidence. However, dentists are expressing concern over ambiguous dental implant guidelines and protocols. Implant survival, success and failure rates have been reported differently for various modalities and justified differently in various research. This lack of consensus appears to stem from erroneous or non-standardized study designs, yielding inconsistent results. Therefore, correctly designed and well-reported high-level studies are needed to aid clinicians in treatment decision-making.

INTRODUCTION

Edentulism is a global health issue that negatively affects a patient's quality of life (Kaushik et al., 2018). As a result, the dental profession has constantly endeavored to improve treatment solutions catering to this group of patients. Treatment options have come a long way since, culminating in dental implants, which are the preferred option of treatment in appropriately selected cases. This is due to their unique phenomenon of 'osseointegration' in which the surgical endosseous component commonly manufactured from pure or alloyed titanium or zirconia, forms a microscopic ankylotic bond with the jaw bone, which closely resembles a natural tooth (Albrektsson & Johansson, 2001). Periodontal ligament loss consequent to natural tooth loss results in loss of discriminative proprioception and therefore deficient control over occlusal force magnitude and vectors (Klineberg & Murry, 1999). Proprioception is not replicable by any rehabilitative prosthesis (Mishra et al., 2016). However, osseointegrated dental implants are able to closely mimic this by virtue of mechanoreceptors in the alveolar bone which improve tactile perception of occlusal forces and

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their location in the implant region (Mishra et al., 2016). This phenomenon is termed 'osseoperception' and is reliant on cortico-motor feedback to the masticatory complex (Klineberg & Murry, 1999).

The field of oral implantology has evolved so much since its discovery. Varieties of surgical techniques and protocols have allowed the treatment of an even wider selection of patients. The basis for this evolution is research work that provides a sound scientific basis for clinical application and further improvement in the field. This review, therefore, aims to summarise the status quo of the literature on surgical techniques and protocols of dental implants, and to highlight current disparate areas where more research effort should be focused. In addition, it serves as a rough map for higher evidence to be conducted, one that aids practitioners in more objective clinical decision-making.

1. Implant surgical techniques

1.1. Open flap versus flapless technique

It has been contested that mucoperiosteal flap elevation results in increased site morbidity and swelling as a result of inflammatory exudation (Divakar et al., 2020). In addition, crestal bone loss is increased erratically due to severance of the periosteum which consequently alters vascularization of the underlying bone (Romero-Ruiz et al., 2015; Wadhwa et al., 2015). Also, the less invasive flapless approach is associated with less postoperative pain, lowered peri-implant mucosal inflammation and decreased junctional epithelial height (You et al., 2009). Additionally, intact soft tissue maintains blood supply to the bone underneath and barriers against bacterial influx, thereby preserving alveolar bone height (Brodala, 2009). Nonetheless, flapless surgery is a relatively 'blind' approach. It may present technical challenges of angulation and dehiscence due to incomplete visualization of the underlying bone anatomy (Rousseau, 2010). Moreover, the small mucosal opening or the lack of it may result in epithelial tissue transfer to the implant-bone interface and impeding osseointegration (Wadhwa et al., 2015). However, it has been reported that both approaches share similar marginal bone loss and clinical outcomes (Lemos et al., 2020).

1.2. Conventional versus piezosurgical osteotomy

Although costly and more time-consuming, more predictable osseointegration is reported in piezosurgical implant osteotomies. They also have a high osteogenic effect and decreased RANKL and proinflammatory cytokines like IL-1β and TNFα (Peker Tekdal et al. 2016; Preti et al. 2007). This is because piezosurgery is less traumatic in bone cutting and more conservative to soft tissues (Maglione et al. 2019). As a result, vital soft tissue structures are spared from inadvertent damage and blood perfusion in the peri-implant microcirculation is maintained. Also, its influence on bone remodelling and osteoblast viability is minimal (Esteves et al. 2013). In addition, resonance-frequency analyses show implants placed with piezosurgical osteotomy have significantly higher implant stability quotient (ISQ) values than implants of conventional drilling (Da Silva Neto, Joly, and Gehrke 2014). On the other hand, it has also been reported that the correct sequential use of conventional drills under copious irrigation results in a better overall clinical outcome than piezosurgery (Labanca et al. 2008a). This is thought to be due to the more widespread use of conventional drills and operator learning curve (Labanca et al. 2008b). However, differing reports suggest that irrespective of osteotomy technique, marginal bone loss and clinical outcomes are comparable after the three-month mark (Amghar-Maach et al. 2018; Sendyk et al. 2018).

1.3. *Alveolar ridge augmentation techniques*

Atrophic ridges can be augmented horizontally or vertically depending on the dimension of need. Narrow ridges can be augmented by split-crest osteotomy or lateral augmentation. Split-crest osteotomy is more time-efficient because implants can be installed within the same surgery. It is also more predictable

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and less morbid to patients (Bassetti, Bassetti, and Bosshardt 2016). The reported average bone gain attained in this technique is 3.61-3.69mm depending on the type of instrument used, and the implant survival rate was 97% (Waechter et al. 2017). Meanwhile, lateral augmentation is more technique sensitive as graft and membrane stabilization are challenging, and often require other fixation techniques. However more bone gain is attained in this technique with a mean gain of 3.9mm and a similarly high implant survival rate (Gorgis et al. 2021). Vertical ridge augmentation can be attained by both onlay or inlay grafting, distraction osteogenesis or guided bone regeneration (GBR) (Urban et al. 2019). GBR is only predictable in small and confined multiwall peri-implant defects (Melcher 1976). The most common complications in this technique are soft tissue dehiscence and membrane exposure (Tay et al. 2020). This often necessitates membrane removal which consequently jeopardizes tissue regeneration at the site. In distraction osteogenesis, 21.6-57.8% bone gain is achievable after a 12-week consolidation period (Vega and Bilbao 2010). Therefore, its use is reserved for 6-10mm defects, particularly in the anterior zones (Vega and Bilbao 2010). A complication of distraction osteogenesis is relapse bone loss, hence 15-20% overcorrection is recommended (Saulacic et al. 2005; Wolvius et al. 2007). To further minimize bone loss, implants inserted into distracted bone are preferably maximally engaging wide and long implants, functionally loaded within standard time (Vega and Bilbao 2010). In onlay grafting, the bone graft is placed subperiosteally, atop the crestal bone. In this technique, the blood supply to the graft is more hampered, hence the success rate is only 74% (Torres et al. 2019). In the inlay grafting or sandwich osteotomy technique, the bone graft is interposed between a coronally osteotomized bone and basal bone with blood supply relatively maintained via lingual tissues (Roccuzzo et al. 2020). The reported complications in vertical ridge augmentation techniques include compromised perfusion due to distance from root vessels (Urban et al. 2019), nerve dysesthesia, bone/graft dehiscence and mucosal rupture (Sezavar et al. 2015). Interestingly, all three techniques shared similarly high survival rate (J. Li et al. 2017; Salter 2001).

1.4. **Crestal versus subcrestal placement**

There is a persisting debate regarding implant insertion depth with better survival and effect on marginal bone loss (Donovan et al. 2010; de Siqueira et al. 2017). Subcrestal implant placement is advocated because it prevents thread and rough surface exposure to biofilm flora, thereby reducing the incidence of peri-implant disease (de Siqueira et al. 2017). It has also been recommended in thin mucosal biotypes prone to recession and subsequent crestal bone resorption (Palacios-Garzón et al. 2018). Additionally, literature supporting the subcrestal approach claims a 2% higher chance of early failure in non-submerged implants (Troiano et al. 2018). On the other hand, equicrestal placement seems to increase the intrasulcular space around the implant and re-establishes appropriate biological width (Cardelli et al. 2014). It also avoids bone destruction from Gram-negative anaerobic bacteria proliferating in the deeper oxygen-starved zones (Valles et al. 2018). Nonetheless, both surgical techniques were found to have a similar average marginal bone loss of 2.05 +/- 0.16mm at 12-month and three-year reviews (Cardelli et al. 2014).

2. **Implant surgical protocols**

2.1. *Timing of implant placement*

Immediate implant placement into the fresh post-extraction socket is merited with shorter treatment time, early aesthetics and patient satisfaction. They are also credited with better preservation of peri-implant bone and reduced need for augmentation procedures (Peñarrocha-Oltra et al. n.d.). This is due to the early stimulatory effect of occlusal forces subjected to them, which are transmitted directly to the alveolar bone (Jalaluddin et al. 2021). They are found to result in similar marginal bone loss to delayed placement in the fully healed socket (4-6 months after exodontia) (Peñarrocha-Oltra et al. n.d.) and a low annual failure rate of 0.5-1.4% (Lang et al. 2012). However, they have also been reported with 30% failure in primary healing, and five times the incidence in delayed implants in the aesthetic zone (Lang et al. 2007). Moreover, greater

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marginal bone loss has been reported in immediate placement, especially in the buccal plate and two-fold the complications in delayed implants (Garcia-Sanchez et al. 2022). Thus, some authors discommend this approach in the aesthetic zone (Araújo et al. 2005). Compared to delayed implants, immediate implants have poorer primary stability and suboptimal clinical outcome as the native bone is still deficient in both density and volume (Tonetti et al. 2017). However, the survival rate of implants in both approaches was found to be akin (In ’t Veld, Schulten, and Leusink 2021). Early or immediate-delayed implant placement on the other hand, refers to implant placement within 4-16 weeks post-extraction. During this period, soft tissue healing is complete but without substantial bone fill in the socket (Soydan et al. 2013). It offers a shorter treatment time than delayed placement but superior three-dimensional hard tissue stability and primary wound closure compared to immediate placement (Bassir et al. 2019; Sanz et al. 2012). With regards to clinical outcomes, early implant placement is reported with less MBL than immediate placement, but similar survival rate and failure risk compared to both immediate and delayed placement protocols, even after a 10 year follow-up (Bassir et al. 2019; Chen and Buser 2009).

2.2. *Tissue level versus bone level placement*

Tissue level placement is thought to be clinically superior because the transepithelial collar of the implant helps reduce marginal bone loss and bacterial accumulation by providing better access to oral hygiene (Agustín-Panadero et al. 2021). This is also validated by the absence of an implant-abutment microgap which harbours chronic inflammatory infiltrate responsible for the elevation of periodontal indices (Hernández-Marcos, Hernández-Herrera, and Anitua 2018). On the contrary, it was noted that bone level placement produces more favourable bone level changes and osseointegration. This was owed to a greater bone deposition along the implant shoulder, enhanced primary stability and decreased crestal bone stress, especially in implants with mismatched implant-abutment junction (Hadzik et al. 2017; Kumar et al. 2014). This is because of biological width re-establishment and stabilization of the marginal bone (Kumar et al. 2014). Recently, however, it is assumed that the fluctuation of outcomes between the two surgical approaches is more likely the effect of confounding factors such as surface modification, implant geometry and platform design rather than the placement level itself (Agustín-Panadero et al. 2021; Candotto et al. 2019).

2.3. *Axial versus tilted angulation*

Occlusal forces subjected perpendicularly to axially placed implants are perceived better. Unlike natural teeth, implants are not anchored to the alveolus by the periodontal ligament, which is absorptive to compressive and tensile stress. Instead, they are bound by resistive calcified tissue (W.-S. Lin and Eckert 2018). Thus, axial implants are thought to better sustain occlusal load and ultimately result in less marginal bone loss (Mehta et al. 2021). Conversely, tilted implants can spare vital structures and preclude the use of more complex procedures like nerve repositioning and sinus elevation surgeries (Asawa et al. 2015). They also resolve space insufficiency by enabling the use of longer implants with greater surface area for osseointegration (Monje et al. n.d.) and better anteroposterior implant distribution in the edentulous span (Hamilton et al. 2021). Despite the notion that multidirectional forces in the oral cavity are traumatic and resorptive to the peri-implant bone, evidence shows that distally angulated implants dissipate occlusal stress better than straight implants (Del Fabbro et al. 2012). This is especially evident in the All-on-Four technique which employs two non-axial posterior implants (Ioannis V 2010). Additionally, their cumulative success rate in the posterior maxilla was found to be as high as 98% (L Krekmanov, M Kahn, B Rangert 2000). However, the angulation may increase stress at the implant-abutment junction, which increases marginal bone loss (Brosh, Pilo, and Sudai 1998). Therefore, the judicious use of angulated implants is necessary. Tilted implants are better reserved for splinted restorations in denser bone types of D3 and above according to Misch classification, and tilt angulation should be kept below 30 degrees (Maló, Rangert, and Nobre 2003).

2.4. *One- versus two-stage healing protocol*

In the one-stage protocol, immediate placement of a transmucosal healing abutment reduces overall treatment time and precludes trauma from a second surgery (Gheisari, Eatemadi, and Alavian 2017). Additionally, the resultant marginal bone loss was found comparable to that of the two-stage protocol (Esposito et al. 2009). Its application however has been cautiously reserved for sites of light occlusal load (Byrne 2010). In the two-stage surgical protocol, although the gratification of early aesthetics is delayed, the approach prevents premature loading of the implant and provides a period of uninterrupted healing (Byrne 2010). It is also the preferred protocol in guided bone regeneration with membranes (Esposito et al. 2010). Yet, due to repeated intrusion and manipulation of the surgical site, others reported that the marginal bone loss is significantly higher than in the one-stage approach (Chaushu et al. 2020).

2.5. *Computer-guided versus freehand surgery*

Computer-guided implant placement comes with higher time and financial bearings because it requires a special surgical template that is CAD/CAM-milled from a 3D-computer software. It may be dynamic wherein surgical steps are visualized and monitored in real-time, or static wherein the surgical template guides either the pilot penetration or the entire sequence (Yogui et al. 2021). It greatly improves insertion precision and interim prosthesis accuracy with fewer chairside adjustments. It also effectively reduces treatment time (Hultin, Svensson, and Trulsson 2012; Moon et al. 2016). When placement accuracy is compared, fully-guided placement and partially-guided (pilot drill-guided) perform similarly in terms of positioning accuracy, but fully-guided placement is superior in terms of angular deviation, particularly in healed areas (Tattan et al. 2020). However, partially-guided technique is advantageous in narrow sites that restrict placement of fully-guided surgical stents (Gelpi et al. 2023). Both techniques are akin in terms of implant success parameters (Guentsch et al. 2021). Computer-guided surgery also decreases postoperative morbidity and side effects and allows the use of a flapless approach (Hultin, Svensson, and Trulsson 2012). Freehand placement on the other hand is implicated in more pronounced post-operative oedema and pain (Yogui et al. 2021), but better tactility of insertion depth (Junying Li et al. 2019). Heat generation from drilling is also better dissipated in the freehand approach because of the better reach of irrigation solution to the drill tip (Gargallo-Albiol et al. 2019). Contrariwise, the surgical template used in the computer-guided technique impedes adequate irrigation and may cause higher temperature rises in the bone and possible osseodisintegration (Gargallo-Albiol et al. 2019). Variably, both techniques share similar implant survival and complication rates (Yogui et al. 2021) but with an inappreciable 0.4mm decrease in bone loss in the computer-guided approach after a five-year review (Tallarico et al. 2018).

3. **Implant recipient site**

3.1. *Bone quality*

The quality of edentulous residual alveolar bone has been categorized into four universally accepted groups, D1, D2, D3 and D4, based on the amount of cortical and cancellous bone (Lekholm and Zarb 1985). Regions of the alveolar ridges are matched to this classification as a rough guide, as human bone shows variable density even within the same region (Ulm et al. 1999). Theoretically, implants placed in dense bone such as D1 tend to exhibit better primary stability (Stefan Rues, Marc Schmitter, Stefanie Kappel, Robert Sonntag, Jan Philippe Kretzer 2021). This is because dense bone restricts implant micro-mobility and allows undisturbed osseointegration (Sukumaran Anil 2015). However, this is disputed by better vascularity in bone with higher trabecular content (Vivian Wu, Engelbert A. J. M., Marco N. HelderChristiaan M. ten Bruggenkate 2022), and a larger reserve of progenitor cells with osteogenic

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potential (Eming, Martin, and Tomic-Canic 2014). Additionally, the strain of load remains high in the predominantly cortical bone which favours fibrous tissue formation instead of osseointegration (Salter 2001). Also, primary stability is not governed reliably by the density of the peri-implant bone alone (Stefan Rues, Marc Schmitter, Stefanie Kappel, Robert Sonntag, Jan Philippe Kretzer 2021). In contrast, more predictable osseointegration manifests in bone with a higher cancellous substance such as D3 bone (J. Li et al. 2017). This is because the collagen matrix begins to lay down in the peri-implant fibrin clot which subsequently calcifies, resulting in stiffening of the intercortical bone and implant osseointegration (J. Li et al. 2017). Thus, optimal osseointegration and succeeding clinical outcomes are the result of an environment of reduced implant micromotion and successful deposition of mineralizing collagen matrix in the peri-implant vicinity (J. Li et al. 2017; Sukumaran Anil 2015).

3.2. *Soft tissue quality*

Thin soft tissue phenotype is a risk factor for peri-implant tissue dehiscence (Kan et al. 2018) as pronounced marginal bone loss ensues 12 months after placement (Saglanmak et al. 2021). Hence, there is literature consensus for the superiority of greater tissue thickness over thin biotypes, especially in platform-matched implants (Cochran et al. 1997; Di Gianfilippo et al. 2020). This is because thicker soft tissue provides a protective seal over the underlying bone which hinders the influx of bacteria. In turn, peri-implant diseases and marginal bone loss are reduced (Suárez-López del Amo et al. 2016). Furthermore, thicker mucosa is able to mask the grey hue of titanium implants resulting in better aesthetics and greater patient satisfaction (Giannobile, Jung, and Schwarz 2018). There is no agreement however as to the measurement of sufficient thickness (Akcalı et al. 2017) and no gold standard method to measure this (Saglanmak et al. 2021). Reports have varied as to the limit below which significant bony recession ensued. Previously it was assumed to be 2mm (Akcalı et al. 2017; Linkevicius et al. 2009), but more recently it was proven that ≥2.5mm should be the cut-off (Saglanmak et al. 2021). Effect of pre-existing keratinization of mucosa and need for keratinized band augmentation around dental implants remains controversial (Greenstein and Cavallaro 2011). Some reports state that keratinized band thickness in peri-implant mucosa is directly proportional to reduced plaque accumulation, risk of mucositis and clinical attachment loss (G.-H. Lin, Chan, and Wang 2013). It hinders penetration of pathogenic bacteria, and correlates to lower Prostaglandin E2 levels, thus, hampering onset of peri-implant disease (Zigdon and MacHtei 2008). As a result, it has a stabilizing effect on the marginal bone and better implant clinical outcome (100). Although, in other reports reduced keratinization was not found to directly affect peri-implant indices of plaque accumulation and bleeding on probing (Ravidà et al. 2022), it offers a resilient and protective 'cuff' around the implant which seems to contribute to overall implant success (Farhoudi and Parsay 2018).

CONCLUSION

Current literature reveals a discrepancy in research findings despite its sizeable volume. Treatment gold standards that aid practitioners in clinical decision-making pertaining to dental implant surgery are yet to exist. Therefore, this calls for more robust research efforts of the highest standard to provide practitioners with more clear-cut data for their clinical practice.

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AUTHORS' CONTRIBUTIONS

Fatima Al Khateeb carried out the research, wrote and revised the article. Tan Su Keng and Fatima Al Khateeb conceptualised the central research idea and provided the theoretical framework. Tan Su Keng and Hazmyr Abdul Wahab designed the research, supervised research progress; Tan Su Keng anchored the review, revisions and approved the article submission.

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