Dentistry Review 2 (2022) 100042

Contents lists available at ScienceDirect

Dentistry Review

journal homepage: www.elsevier.com/locate/dentre

Occlusal considerations for full-arch implant-supported prostheses: A guideline

Douglas Yoon[a], Darshanjit Pannu[a], Melissa Hunt[b,*], Jimmy Londono[a]

[a] Advanced Education Program in Prosthodontics, Department of Oral Rehabilitation, Dental College of Georgia at Augusta University, Augusta, Ga, Georgia
[b] Department of General Dentistry, Dental College of Georgia at Augusta University, Augusta, Ga, Georgia

A B S T R A C T

Full-arch implant prostheses of various types and materials have become a popular treatment modality for edentulous arches. Studies have found that the prevalence of prosthetic complication is higher than biological complication with these restorations. Occlusion may be one of the contributing factors for prosthetic complications in full-arch implant supported prostheses. However, available literature regarding the occlusal scheme of full-arch implant prostheses is often insufficient or unclear. Often the articles do not give details regarding the material type or the opposing dentition. The occlusal scheme should not only provide the patient with function and comfort, but also minimize the risk of various prosthetic complications. Metal-acrylic and all-ceramic are popular material options for full-arch implant supported prostheses. The proposed guideline will suggest occlusal considerations based on material type (metal-acrylic or all-ceramic) as well as the opposing dentition (natural or prosthetic dentition) in order to minimize prosthetic complications. Five possible scenarios are presented: 1) Metal-Acrylic vs. Metal-Acrylic 2) Metal-Acrylic vs. Natural Dentition 3) All-Ceramic (Zirconia) vs. All-Ceramic (Zirconia) 4) All-Ceramic (Zirconia) vs. Metal-Acrylic 5) All-Ceramic vs. Natural Dentition. The guidelines are based on compilation of available occlusal concepts from natural teeth and implant prosthetics.

Introduction

Full-arch fixed implant-supported prostheses can be a treatment option for patients presenting with failing dentition or complete edentulism. Full-arch implant-supported prostheses (immediately or conventionally loaded) have shown very high (90% or greater) survival rates in short-term retrospective studies and high patient satisfaction in surveys [1,2,3].

Metallic framework with processed acrylic resin has been a popular material for implant-supported prostheses. Some advantages of metal-acrylic include relative ease of fabrication, proven clinical performance, cost effectiveness, and repairability [4–9]. In recent years, with the advancements in Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology, layered or monolithic high-strength ceramics such as zirconia have become popular alternative materials for fixed implant supported prostheses [10,11,23,24]. Zirconia offers advantages such as high tensile strength, improved esthetics, wear resistance, and excellent biocompatibility [12–15].

Regardless of the prosthetic material, prosthetic complications are more prevalent compared to biologic complications [1,2]. In addition, higher rates of prosthetic complications have been reported in cases where full arch implant prostheses oppose natural teeth or fixed restorations [23]. Prosthetic complications can include acrylic tooth fracture, veneering porcelain chipping, screw loosening/fracture, premature wear of acrylic teeth, and framework fracture [2,11,16–18]. Such prosthetic complications can lead to multiple repair visits incurring laboratory costs, and more importantly, dissatisfied patients.

Occlusion is a risk factor that can contribute to prosthetic complications of full-arch implant-supported prostheses. However, very little information is available regarding the occlusal schemes of full-arch implant-supported prostheses. Most available studies only briefly mention, if at all, the occlusal scheme used in the prosthetic design. For example, Malo reports long term success of all-on-four prostheses with various materials, but does not specify occlusal scheme other than to state that the restorations “mimic natural teeth.” [24] The selection criteria for a certain occlusal scheme are often based on empirical evidence or the clinician’s own occlusal philosophy. To add to the uncertainty, the occlusal considerations for different material types (metal-acrylic or all-ceramic) or the opposing dentition (artificial or natural) are often omitted from studies. For a novice clinician, a simplified guideline would be helpful when planning the occlusion of full-arch implant-supported prostheses of various materials opposing artificial or natural dentition.

After review of prosthodontic occlusal concepts from natural dentition to fixed and implant-supported restorations, the authors have developed an occlusal guideline for five possible scenarios of full-arch implant supported prostheses: 1) Metal-acrylic vs Metal-acrylic 2) Metal-acrylic vs Natural dentition 3) All-ceramic vs All-ceramic 4) All-ceramic vs Metal-acrylic 5) All-ceramic vs Natural dentition (Table 1). The goal of the guideline is to maximize patient comfort and function while minimizing prosthetic complications.

* Corresponding author.
E-mail address: mehunt@augusta.edu (M. Hunt).

https://doi.org/10.1016/j.dentre.2022.100042
Received 25 January 2022; Received in revised form 1 March 2022; Accepted 3 March 2022
2772-5596/© 2022 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Table 1
Summary of different scenarios that may present as a choice during full arch/full mouth rehabilitation with implant supported prostheses.

	Centric Contact	Excursive movements	Zr framework Design
Scenario 1.	-Simultaneous bilateral contact	-Laterotrusion: Group function	N/A
Metal-Acrylic	-Shimstock clearance (10μm) on cantilevers and anteriors	-Protrusion: Shallow anterior guidance	
Vs	-Freedom in centric(1.0–1.5 mm)	-No contact on cantilever	
Metal-Acrylic			
Scenario 2.	-Simultaneous bilateral contact	-Laterotrusion: Canine guidance (sound canine) Group	N/A
Metal-Acrylic	-Shimstock clearance (10μm) on cantilevers and anteriors	function (compromised canine)	
Vs	-Freedom in Centric(1.0–1.5 mm)	-Protrusion: Shallow anterior guidance	
Natural Dentition		-No contact on cantilever	
Scenario 3.	-Simultaneous bilateral contact	-Laterotrusion: Group function	-Full contour monolithic
All Ceramic/Zirconia	-Equal intensity contact on posteriors and anteriors	-Protrusion: Shallow anterior guidance	-Veneering porcelain
Vs	-Shimstock clearance (10μm) on cantilevers	-No contact on cantilever	limited to facial/buccal
All Ceramic/Zirconia	-Freedom in centric (1.0–1.5 mm)		
Scenario 4.	-Simultaneous bilateral contact	-Laterotrusion: Group function	-Full contour monolithic
All Ceramic/Zirconia	-Shimstock clearance (10μm) on cantilevers	-Protrusion: Shallow anterior guidance	-Veneering porcelain
Vs	-Freedom in centric(1.0–1.5mm	-No contact on cantilever	limited to facial/buccal
Metal Acrylic			
Scenario 5.	-Simultaneous bilateral contact	-Laterotrusion: Canine guidance (sound canine)	-Full contour monolithic
All Ceramic/Zirconia	-Shimstock clearance (10μm) on cantilevers and anteriors	Group function (compromised canine)	-Veneering porcelain
Vs	-Freedom in centric(1.0–1.5 mm)	-Protrusion: Shallow anterior guidance	limited to facial/buccal
Natural Dentition		-No contact on cantilever	

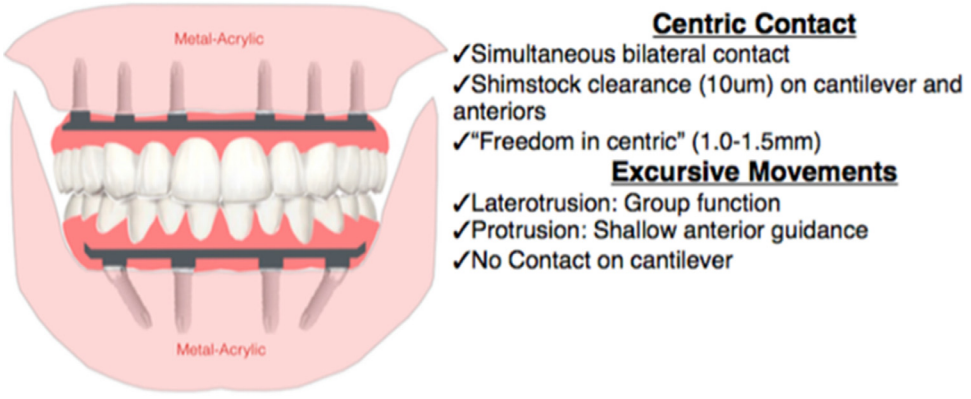


Fig. 1. Metal-acrylic opposing metal-acrylic.

Methods

From September 1, 2018 to October 2021, online search was performed through electronic database PubMed and ScienceDirect. The following keywords were used: "Implant occlusion," "Full-arch prosthesis," "Occlusal scheme," "Implant-supported prosthesis," "Zirconia," and "Metal acrylic." Twenty-four articles were selected for review. Textbooks and classic literature pertaining to natural, fixed and implant occlusion were also reviewed Fig. 1.

Guidelines

Scenario 1: metal-acrylic vs metal-acrylic (Fig. 1)

Regardless of prosthetic material or opposing dentition, simultaneous bilateral centric contact prevents premature contacts, distributes even occlusal forces, promotes occlusal stability, and aids in patient comfort. Less occlusal forces should be delivered on the anterior teeth and distal cantilevers by providing clearance of Shimstock (~10μm) in occlusion. Falk et al. found that distal cantilevers bore 70% of occlusal forces compared to 30% by the fixture supported portion in mandibular fixed prostheses. Slight relief in occlusal forces in the distal cantilevers can reduce the risk of fracture and over-stressing the terminal implant and abutment. Anterior denture teeth in metal-acrylic full-arch prostheses can be considered a "weak link." Anterior denture teeth are generally narrower in width both mesio-distally and bucco-lingually than posteriors. Anterior denture teeth typically have less denture resin base circumferentially around the tooth, especially along the labial surface. In addition, anterior teeth generally receive occlusal forces at an off-axis angle, which often directs forces toward the labial aspect. Therefore, anterior denture teeth are naturally more prone to fracture from the denture resin base. Priest et al. also reported anterior tooth fracture to be more common compared to posterior teeth in metal-acrylic full-arch prostheses.

Freedom in centric as described by Schuyler is recommended when designing the centric contacts. The incorporation of 1.0–1.5 mm of flattened occlusal surfaces will allow some degree of freedom from centric position. The allowance of freedom from centric position will aide in patient comfort, especially for patients who are completely edentulous and have thus lost proprioception.

Group function is recommended for laterotrusive movements. By sharing the occlusal load among posterior teeth, canine denture teeth will be spared from receiving excessive occlusal stress during excursive movements. As described by Abduo, group function occlusion allows for amore lateral and shallow chewing pattern, which is in contrast to chewing patterns of canine guidance occlusion [20]. Group function occlusion allows more mandibular freedom, which would aid in patient comfort and lessen mechanical stress to the prostheses during function. Excursive contacts on distal cantilever are shown to cause fracture of the cantilever; therefore, should be avoided [21]. Shallow anterior guidance is recommended in protrusion in order to decrease occlusal forces. The occlusal forces should be shared evenly across incisors from centric contact leading up to edge-to-edge position [22]. Slight vertical overlap of the anterior teeth is needed to achieve anterior guidance will also improve the esthetic outcome Fig. 2.

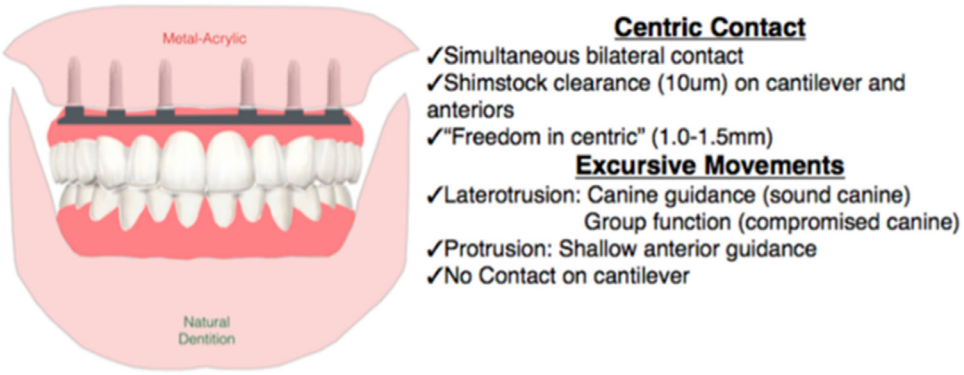


Fig. 2. Metal-acrylic opposing natural dentition.

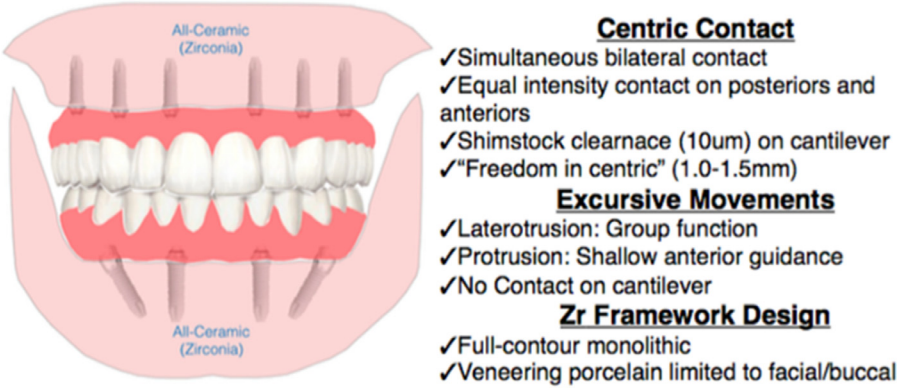


Fig. 3. All-ceramic opposing all-ceramic.

Scenario 2: metal-acrylic vs natural dentition (Fig. 2)

Occlusal considerations for centric contacts should be the same as scenario 1. Relatively light centric contacts (10μm shimstock clearance) on natural anterior teeth and firm contacts on posterior teeth are still preferred. Slight anterior clearance will "protect" the anterior teeth from occlusal overload as well as reduce the risk of anterior denture teeth fracture. If periodontally healthy natural canines are present, shallow canine guidance is recommended during laterotrusive movements. Shallow anterior guidance is also recommended in protrusion. Studies have shown that disocclusion of posterior teeth in excursive movements led to reduction in EMG activities of the temporalis and masseter muscles [21]. The reduction of masticatory muscle activities can decrease the overall occlusal forces delivered to the prosthesis in excursive movements. This, in turn, will decrease the risk of prosthetic complications such as premature wear of denture teeth, denture teeth fracture, or framework fracture. Another advantage of incorporating canine guidance is the relative ease of fabrication for the clinician and laboratory technician. Meticulous process of programming the articulator, designing and timing the excursive contacts, and tedious intra-oral occlusal adjustments can be reduced. However, if natural canines are periodontally compromised, group function is recommended in order to share the laterotrusive load amongst the bicuspids and protect the canine from occlusal overload Fig. 3.

Scenario 3: all-ceramic (Zirconia) vs all-ceramic (Zirconia) (Fig. 3)

The recommendation of centric occlusion for all-ceramic full-arch prosthesis deviates from metal-acrylic in one aspect. Having a monolithic, milled prosthesis eliminates the weak link effect of anterior denture teeth found in metal-acrylic prosthesis. Therefore, a more equal intensity occlusal contacts can be applied in the anterior and posterior regions. Even and broad distribution of occlusal forces across the prosthesis can be favorable in high-strength ceramics such as zirconia, where flexibility of the material is very limited. The distal cantilever, however, should still exhibit shimstock clearance (10μm).

One of the common complications of porcelain fused to zirconia is chipping of the veneering porcelain. Short-term studies reported that full-arch implant-supported prostheses fabricated with either full-contour, monolithic zirconia or zirconia with layering porcelain limited to facial/buccal surfaces showed very high prosthetic success rates. In order to minimize porcelain chipping, especially on high-risk patients such as those with bruxism, incorporating zirconia on incisal and occlusal surfaces is recommended Fig. 4.

Scenario 4: all-ceramic (Zirconia) vs metal-acrylic (Fig. 4, 4A, 4B, 4C, 4D)

When all-ceramic full-arch prosthesis is opposing a metal-acrylic prosthesis, the anterior denture teeth become the weak link (as mentioned in Scenario 1.) Therefore, shimstock clearance (10μm) on the anteriors is recommended to decrease the risk of anterior denture teeth fracture Fig. 5.

Scenario 5: all-ceramic (Zirconia) vs natural dentition (Fig. 5)

Similar to Scenario 2, shimstock clearance (10μm) of the anterior teeth will protect the natural anterior dentition from occlusal overload. Canine guidance is recommended in the presence of healthy natural canines. However, group function is recommended if the canines are periodontally compromised.

Discussion

The limitation of these guidelines is the lack of long-term clinical data to provide strong evidence. The guideline is largely based on compilation of occlusal concepts from natural teeth, fixed, and implant prosthodontics. Various occlusal concepts were applied in hopes of reducing unfavorable occlusal forces onto the implant prostheses and opposing dentition in order to reduce mechanical complications. Occlusion

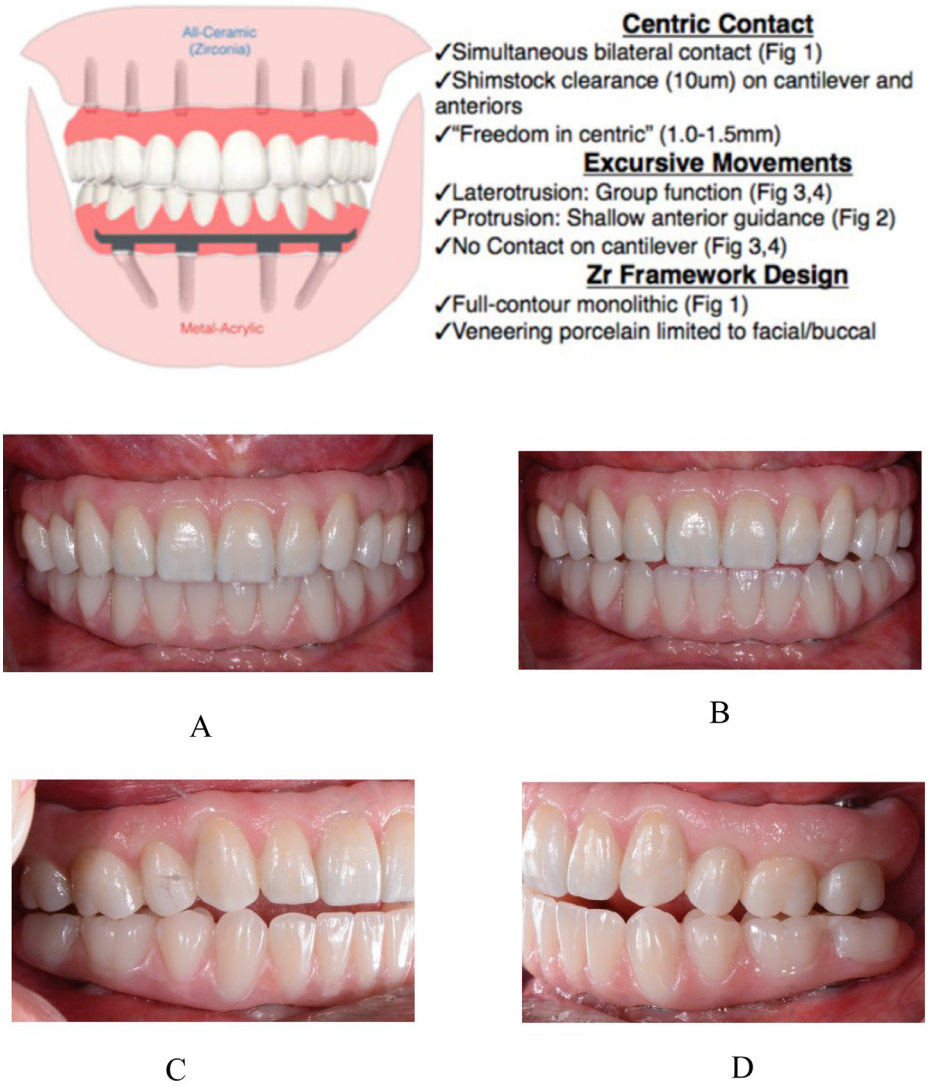


Fig 4. All-ceramic opposing metal-acrylic.
A. All-ceramic (zirconia) opposing metal-acrylic. Centric.
B. Protrusive.
C. Right lateral.
D. Left lateral.

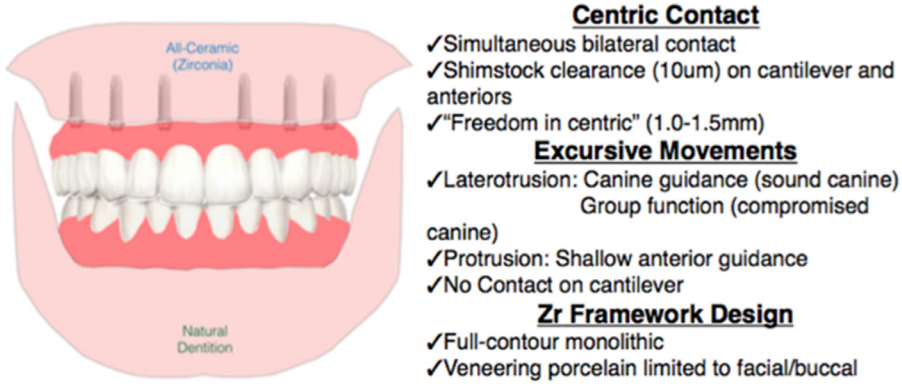


Fig 5. All-ceramic opposing natural dentition.

has always been a topic of controversy, as so much of it is based on theory or observation. Well-controlled, long-term studies with large sample size comparing different occlusal schemes are difficult to design. Thus, strong scientific evidence is often lacking when it comes to occlusion or occlusal schemes. In addition, much less literature is available regarding occlusion of full-arch implant prostheses of various materials.

Some authors argue that choosing a particular occlusal scheme has little clinical significance. This is because most patients are able to adapt to minor changes in occlusal schemes [19,20]. Even so, one should be aware of differences in natural dentition and implant prostheses. Full-arch implant-supported prostheses are far more rigid compared to natural dentition. In the absence of periodontal ligaments, patients' proprioception is greatly reduced. The diminished proprioceptive feedback combined with rigid implant fixtures and prosthesis requires more attention to biomechanical factors such as occlusion.

Careful treatment planning is essential for full-arch implant-supported prostheses. The present guideline is optimized for patients exhibiting Class I skeletal relation, normal ridge relations, and opti-

mal implant positions. Pre-treatment considerations must include evaluations of skeletal relations, maxillary and mandibular ridge relations (Anterior-Posterior, Buccal-Lingual), esthetic demands, temporomandibular symptoms, vertical dimension of occlusion, planned implant positions, occlusal and periodontal exam of remaining teeth, and parafunctional habits. Such pretreatment considerations may call for modifications to the occlusal design of the prostheses.

Prior to fabrication of the definitive prosthesis, it is prudent to evaluate occlusion and patient comfort at the provisional stage. For metal-acrylic, the occlusion of the provisional prosthesis should be checked and adjusted intra-orally. During the provisional phase, the patient should be evaluated periodically for possible prosthetic complications or discomfort. The teeth set-up for the definitive prosthesis should closely emulate the occlusal scheme of the provisional prosthesis. Nonetheless, some intra-oral occlusal adjustments will be necessary after the delivery of the definitive prosthesis. For all-ceramic, a “functional prototype” prosthesis made of solid PMMA can be milled. The occlusion of the functional prototype prosthesis should be periodically checked and adjusted during the provisional phase of the treatment. When desired occlusal scheme and patient comfort are achieved, the occlusal contours of the functional prototype can be scanned and replicated for the definitive all-ceramic prosthesis via CAD/CAM technology. Replication of the occlusal design of the functional prototype will result in more predictable definitive prosthesis, which would require less occlusal adjustments and aid in patient comfort.

To increase long-term prosthetic success, post-treatment considerations should include periodic recall exams, occlusal guard, and patient education. During recall exams, centric and excursive contacts should be evaluated, along with structural and hygiene status of the prostheses. More frequent recall schedule is recommended for high-risk patients (ie bruxers). Fabrication of a rigid occlusal guard is recommended for patients treated with full-arch implant supported prostheses. Patient’s compliance with the occlusal splint must also be evaluated and reinforced during recall exams. Patients must be well informed of material choice, hygiene and maintenance requirements, and possible complications prior to initiating treatment and again after the delivery of the prosthesis. Patients must also be informed of dietary precautions (ie not chewing on ice, biting on hard candy) as well as parafunctional habits to avoid (ie clenching, nail biting.

Future studies are needed to provide more clarity and general consensus for the occlusal design of full-arch implant-supported prostheses. Various prosthetic materials exhibit different physical properties and must be considered when designing the occlusal scheme.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors thank Dr. Bryan Lara for his assistance with the literature review for this manuscript.

References

[1] Malo P, Rangert B, Nobre M. "All-on-Four" immediate-function concept with Branemark system implants for completely edentulous mandibles: a retrospective clinical study. Clin Implant Dent Relat Res 2003;5(Suppl 1):2–9.
[2] Malo P, Araujo Nobre MD, Lopes A, Rodrigues R. Double full-arch versus single full-arch, four implant-supported rehabilitations: a retrospective, 5-year cohort study. J Prosthodontics 2015;24(4):263–70.
[3] Scala R, Cucchi A, Ghensi P, Vartolo F. Clinical evaluation of satisfaction in patients rehabilitated with an immediately loaded implant-supported prosthesis: a controlled prospective study. Int J Oral Maxillofac Implants 2012;27(4):911–19.
[4] Adell R, Eriksson B, Lekholm U, Branemark PI, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5(4):347–59.
[5] Albrektsson T, Dahl E, Enbom L, Engevall S, Engquist B, Eriksson AR, et al. Osseointegrated oral implants. A Swedish multicenter study of 8139 consecutively inserted Nobelpharma implants. J Periodontol 1988;59(5):287–96.
[6] Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto study. Part I: surgical results. J Prosthet Dent 1990;63(4):451–7.
[7] Kopp CD. Branemark osseointegration. Prognosis and treatment rationale. Dent Clin North Am 1989;33(4):701–31.
[8] Lindquist LW, Carlsson GE, Jemt T. A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. Clin Oral Implants Res 1996;7(4):329–36.
[9] Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto study. Part III: problems and complications encountered. J Prosthet Dent 1990;64(2):185–94.
[10] Venezia P, Torsello F, Cavalcanti R, D’Amato S. Retrospective analysis of 26 complete-arch implant-supported monolithic zirconia prostheses with feldspathic porcelain veneering limited to the facial surface. J Prosthet Dent 2015;114(4):506–12.
[11] Rojas Vizcaya F. Retrospective 2- to 7-year follow-up study of 20 double full-arch implant-supported monolithic zirconia fixed prostheses: measurements and recommendations for optimal design. J Prosthodontics 2018;27(6):501–8.
[12] Abdulmajeed AA, Lim KG, Narhi TO, Cooper LF. Complete-arch implant-supported monolithic zirconia fixed dental prostheses: a systematic review. J Prosthet Dent 2016;115(6):672–7 e1.
[13] Denry I, Kelly JR. State of the art of zirconia for dental applications. Dent Mater 2008;24(3):299–307.
[14] Della Bona A, Kelly JR. The clinical success of all-ceramic restorations. J Am Dent Assoc (1939) 2008;139(Suppl) 8s–13s.
[15] Kelly JR. Dental ceramics: what is this stuff anyway? J Am Dent Assoc (1939) 2008;139(Suppl) 4s–7s.
[16] Priest G, Smith J, Wilson MG. Implant survival and prosthetic complications of mandibular metal-acrylic resin implant complete fixed dental prostheses. J Prosthet Dent 2014;111(6):466–75.
[17] Bhering CL, Mesquita MF, Kemmoku DT, Noritomi PY, Consani RL, Barao VA. Comparison between all-on-four and all-on-six treatment concepts and framework material on stress distribution in atrophic maxilla: a prototyping guided 3D-FEA study. Mater Sci Eng C Mater Biol Appl 2016;69:715–25.
[18] Kim Y, Oh TJ, Misch CE, Wang HL. Occlusal considerations in implant therapy: clinical guidelines with biomechanical rationale. Clin Oral Implants Res 2005;16(1):26–35.
[19] Klineberg I, Kingston D, Murray G. The bases for using a particular occlusal design in tooth and implant-borne reconstructions and complete dentures. Clin Oral Implants Res 2007;18(Suppl 3):151–67.
[20] Abduo J, Tennant M. Impact of lateral occlusion schemes: a systematic review. J Prosthet Dent 2015;114(2):193–204.
[21] Davis DM, Packer ME, Watson RM. Maintenance requirements of implant-supported fixed prostheses opposed by implant-supported fixed prostheses, natural teeth, or complete dentures: a 5-year retrospective study. Int J Prosthodont 2003;16(5):521–3.
[22] Dawson PE. Functional occlusion: from TMJ to smile design. Edinburgh: Elsevier Mosby; 2006.
[23] Chochlidakis K, Einarsdottir E, Tsigarida A, Papaspyridakos P, Romeo D, Barmak AB, Ercoli C. Survival rates and prosthetic complications of implant fixed complete dental prostheses: an up to 5-year retrospective study. J Prosthet Dent 2020;124(5):539–46. doi:10.1016/j.prosdent.2019.11.022.
[24] Maló P, de Araújo Nobre M, Lopes A, Ferro A, Botto J. The All-on-4 treatment concept for the rehabilitation of the completely edentulous mandible: a longitudinal study with 10 to 18 years of follow-up. Clin Implant Dent Relat Res 2019;21(4):565–77. doi:10.1111/cid.12769.