Basic Principles for Implant Supported Overdentures

.ABSTRACT

Aims: Implant supported overdentures combine the retention and support provided by implants with the advantages of removable prostheses and demand careful preoperative planning. The aim of the present article is to provide a clinically based rationale while designing or fabricating such a rehabilitation.
Methodology: In order to conduct this narrative review, evidence based research articles regarding implant supported overdentures published from January 1990 until December 2020 were searched via the MEDLINE (Pubmed) database. The keywords used were "overdentures", "implant overdentures", "implant supported overdentures", implant retained overdentures", "implant assisted overdentures".

Results: Implant supported overdentures have high success rates and compared to conventional ones they provide superior quality of life, well-being, satisfaction and adequate masticatory efficiency. A crucial factor that should be determined preoperatively is the number and position of implants that need to be placed. Preoperative three-dimensional assessment is of utmost importance to avoid mistakes like the construction of bulky restorations or the absence of adequate material in crucial areas of the restoration with the subsequent acrylic tooth/connector detachment and aesthetic compromise. Selection of the appropriate retentive system depends on the number and the distribution of implants, the desired retention, the morphology of the ridge, the intermaxillary relation, the available prosthetic space, the vertical and horizontal dimensions, the patient's needs and desires, the oral hygiene and the cost. Special care should be given to impression making procedures as well as framework design and fabrication. If the abovementioned are taken into account, subsequent complicatons are reduced. However, frequent maintenance appointments should be scheduled.

Conclusion: Several concerns arise when choosing an implant supported overdenture that mainly refer to the special characteristics defining its function. The key element is the careful preoperative planning of the restoration since it affects the long-term behavior of the prosthesis in terms of technical and biological complications and the frequency of the clinicians reinterventions.

Keywords: Implants, overdentures, removable,

1. INTRODUCTION

Edentulism emerges as a result of periodontal disease, caries or trauma. Resorption of residual ridges, deterioration of masticatory ability, impairment of phonetics and aesthetics, as well as the subsequent psychological burden are some of the negative impacts of tooth loss [1]. This condition has been connected with well-documented consequences upon general health and oral health related quality of life [2].

Rehabilitation of completely edentulous patients has always been a clinical challenge for the dentist who needs to find the most appropriate individualized prosthetic approach for the patient via a well-structured diagnostic process. This includes a thorough clinical and radiographic examination combined with data analysis from patient's medical and dental history along with their demands and desires consideration.

Conventional rehabilitation of edentulous arches can be accomplished with removable complete dentures. Improvement in the field of implantology has made implant-supported removable or fixed prostheses an additional therapeutic option. Lack of adequate retention and stability, pain and discomfort that are sometimes associated with mandibular complete dentures have led to the suggestion of a two-implant-retained mandibular overdenture as the first choice for the rehabilitation of the lower jaw [3].

Stability and resemblance with the natural dentition provided by fixed prostheses, renders them an appealing alternative. However, anatomical limitations affecting implant number and distribution, jaw anatomy influencing the lip and facial muscles support, together with patient's needs and financial restrictions make removable prostheses a considerable option.

The aim of the present review is to present clinical-based guidelines regarding advantages, treatment plan considerations, prosthesis design, techniques and materials for fabrication and maintenance of implant-supported overdentures.

2. MATERIAL AND METHODS

In order to conduct this narrative review, evidence based research articles regarding implant supported overdentures published from January 1990 until December 2020 were searched via the MEDLINE (Pubmed) database.

The keywords used were "overdentures", "implant overdentures", "implant supported overdentures", implant retained overdentures", "implant assisted overdentures".

Articles written in English, peer-reviewed articles and articles elaborating on any aspect regarding the preoperative plan, design, fabrication, indications, advantages, maintenance and complications of implant supported overdentures were set as the inclusion criteria. Duplicates, and articles not focusing on aspects of the rehabilitation with implant supported overdentures were excluded.

3. RESULTS AND DISCUSSION

Initial search yielded 3,307 records. After exclusion of duplicate articles, two reviewers (D.P. and T.K.S.) evaluated the remaining articles by a gradual screening of titles, abstracts and full texts. The same reviewers proceeded to the extraction of relevant data. Available information were grouped and classified into five thematic groups dealing with the:

- Comparison between implant supported overdentures and conventional dentures or implant supported fixed full-arch prostheses
- Factors that should be considered while planning the treatment
- Considerations regarding the selection of retentive attachment type
- Clinical guidelines for the fabrication of implant supported overdentures
- Information regarding maintenance, technical and biological complications

3.1 Implant supported overdentures VS Complete dentures or Fixed implant supported prostheses

Implant supported overdentures have high success rates (>90%) [4] and compared to conventional ones they provide superior quality of life, well-being [5], satisfaction [6] and adequate masticatory efficiency [7]. According to McGill's and York's consensus reports, an overdenture supported by two implants is the gold standard for the rehabilitation of the edentulous mandible [3,8].

Compared to fixed prostheses, removable restorations require a reduced number of implants and fewer pre-prosthetic interventions, while they facilitate oral hygiene and repairs. Correction of an unfavorable intermaxillary relationship becomes simpler, while the facial appearance may be superior, due to the supportive presence of flanges [9,10]. It has been demonstrated that there is no substantial difference in masticatory efficiency among fixed and

removable restorations [11]. Lastly it is not mandatory for implant positions to accurately coincide with tooth positions.

3.2 Preoperative planning – Number and position of implants

Implant overdentures are supported by implants and soft tissues while the retention is provided by the retentive elements of the attachments. Implant number and spread are crucial factors affecting the function of the prosthesis. The use of a reduced number of implants leads to a mixed or mucosal support that may lead to an accelerated wear rate of the connectors. On the other hand, a greater number of implants placed over a larger area, creates more rotational axes that prevent denture rotational movements and detachment offering a more “stable” behavior that resembles fixed prosthesis.

Therefore, a crucial factor that should be determined preoperatively is the number of implants that need to be placed. According to the literature, this aspect is more important than the diameter of the implants chosen [12]. Even though there is consensus for the mandible (2 implants), controversy exists among the authors for the maxilla; however, a minimum of 4 implants are commonly suggested [13,14 15].

A significant aspect that also needs to be considered is the position of the implants placed. From a biomechanical point of view the most favorable positions for the anterior region is between lateral incisors and canines (22mm between the 2 mandibular implants [16]), (*Figure 1*) and for the posterior region at the second premolar. Implant inclinations and distribution are among the factors that will determine the freestanding or connected design of the retentive mechanisms [17].

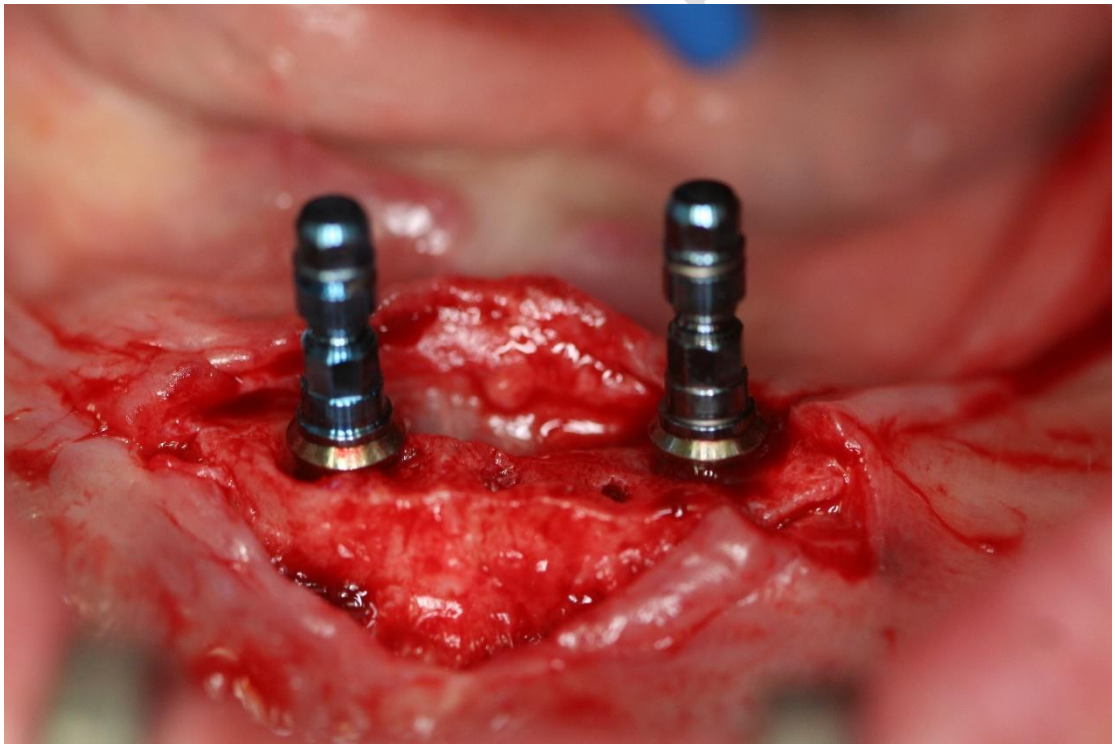

Figure 1. Two implants placed in the position of lateral incisors in the mandible.

Implant positions should not necessarily coincide with the position of the teeth in this kind of prostheses. However, careful planning should offer the possibility for a future upgrade of the existing prosthesis.

Preoperative three-dimensional assessment is of utmost importance to avoid mistakes like the construction of bulky restorations or the absence of adequate material in crucial areas of the restoration with the subsequent acrylic tooth/connector detachment and aesthetic compromise. This is achieved via cast articulation in central relationship and in the

appropriate vertical dimension. Diagnostic set-ups or the use of correctly fabricated dentures allows the assessment of the available space in relation to the connectors with the use of indexes [18].

3.3 Bars VS Stud attachments

Selection of the appropriate retentive system depends on the number and the distribution of implants, the desired retention, the morphology of the ridge, the intermaxillary relation, the available prosthetic space, the vertical and horizontal dimensions, the patient's needs and desires, the oral hygiene and the cost [19].

Regarding the attachments, utilization of a bar requires a vertical space of 13-14 mm while stud attachments offer the potential of rehabilitation in a more limited space (9-12 mm) [20]. However, removable prostheses offer the opportunity of modest alterations of the vertical dimension in order to ensure the desired space in cases of small deficiencies. The horizontal dimension should also be measured since there are some designs like the Hader bar that demand 10-12 mm of space [21].

Some of the commonly used stud attachments, have the advantage of double retention in the inner and outer surface of the stable part of the attachment, they can guide insertion, they respond well to cyclic loading that exceed 60.000 insertion circles -equivalent to 10 years of function-, have the potential of selection of the desired retention, as well as easy replacement when wear emerges [22].

Compared to bars, stud attachments provide more easily accessible and efficient oral hygiene because of their lower height. It is suggested to begin with a retentive nylon insert of reduced retentive strength and to gradually increase it according to patient's capability and demands [23]. The aforementioned choice should be customized to each patient, as a geriatric, probably frail, patient with reduced tactile sensitivity should not be treated as a younger, robust patient.

Bars seem to provide better retention than stud attachments with no impact on patient's satisfaction. Moreover, they offer implant splinting and better stress distribution. The former has been suggested when a prosthesis without palate coverage is desired. It should be mentioned though that in case of absence of palate coverage, implant survival rates do not decrease [24].

Different bar designs offer different rotation and biomechanic performance of the prosthesis. A round cross-section bar provides greater rotation compared to a Dolder or Hader bar. Orientation at the transversal plane also defines the existence of rotational movements. Another benefit of a splinted design is the incorporation of retentive components in locations that do not coincide with implant positions *(Figure 2)*. This feature offers the advantage of correcting the dispersion of the retentive elements while incorporating implants not placed in ideal positions.

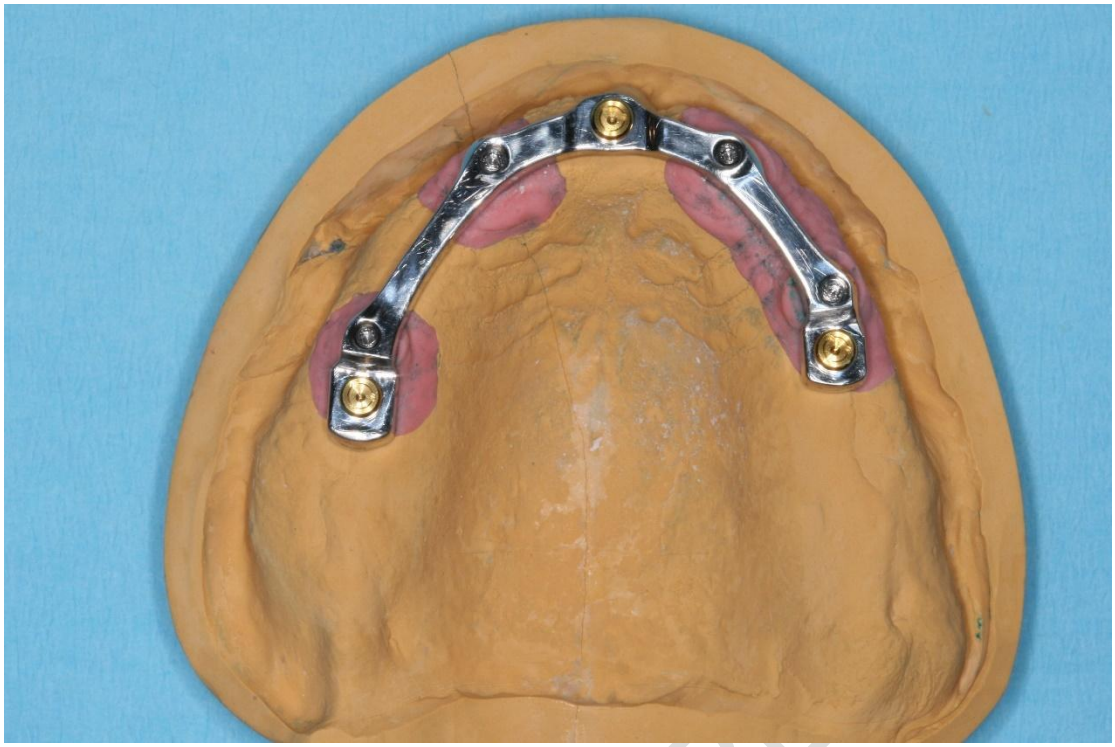

Figure 2. Bar design with incorporated stud attachments placed at positions that do not coincide with implants.

Except for the greater prosthetic space requirements, restorations with a bar are more demanding in terms of design, technical sensitivity, fabrication methods and cost. Impressions should be made utilizing techniques and materials that ensure dimensional accuracy. Impression accuracy should be verified with a jig that is constructed on the final cast and tried intraorally [25].

3.4 Overdenture fabrication guidelines:

Impression making is a crucial step of the fabrication process, in order to precisely transfer the three dimensional position of the implants to the dental laboratory. According to the literature, the open tray technique with splinted impression posts is the most accurate technique regarding conventional impressions[26], especially in cases of non-parallel implants [27]. Nevertheless, precise implant position transfer should not be done in expense of soft tissue impression accuracy, following the principles of conventional dentures. A variety of techniques is available in order to combine the two abovementioned prerequisites [28]. Wax rims with baseplates that can be screwed in one of the placed implants facilitates the intermaxillary record procedure *(Figure 3)*.

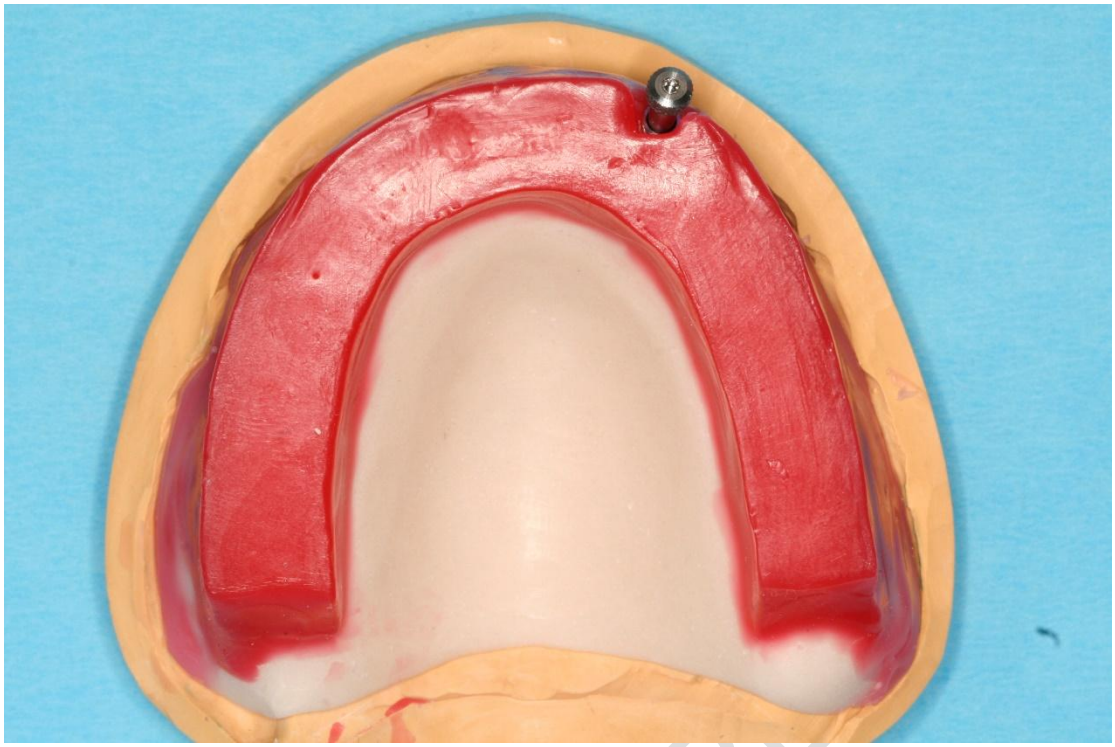

Figure 3. Using one implant for baseplate stabilization enhances the accuracy of the record by eliminating wax rim micromovements.

Fabrication of bars is a technique-sensitive procedure. They should be parallel to the condyles hinge axis and offer a space of 1,5 mm between their lower surface and patient's mucosa. Their extensions should not exceed 10mm. It has been demonstrated that extension from 10 to 20mm increases stresses for about 110% [29].

CAD/CAM technologies are applied for the construction of the bar and the framework of the prosthesis as well, with either additive or subtractive methods [30]. Innovative technologies and techniques that combine polymer bars (PEEK) with zirconia frameworks have emerged. However, long-term studies are required to verify their clinical behavior [31].

To avoid deformation the nylon inserts of the attachment should be incorporated into the prefabricated metal housing and not directly in the acrylic or an extension of the metal framework. Careful design should offer enough space during activation so that the metal housings are surrounded by acrylic, making reinterventions easier. Attachment activation is suggested to take place intraorally. should be placed to avoid acrylic overflow.

3.5 Complications:

Complications that need repair concern the replacement of the attachments, denture relines, replacement of the acrylic teeth and they usually appear within the first year of function [19]. Some authors claim that complications are more frequent in case of stud attachments than bars [32].

Regarding biological complications there is no difference in periimplant indexes among bars and stud attachments. Prosthetic design, bone substrate and arch morphology are more crucial factors [9]. Hyperplasia due to poor oral hygiene and negative pressure is a common complication in bars [33].

In any case, when the treatment plan includes implant supported overdentures, patients should be informed that frequent recalls are needed. According to a study, within 10 years after restoration delivery more than 443 minutes are dedicated to intervention/repairs [34].

DISCUSSION:

Even though the initial costs are high, rehabilitation of edentulism with implant supported prostheses results in improvement of oral health related quality of life (OHRQoL) [35]. Implant supported overdentures comprise a restorative solution that combines improved function [7] compared to conventional dentures and lower costs and surgical interventions as opposed to full-arch implant retained fixed prostheses. The aforementioned can be justified by the McGill consensus according to which an implant supported mandibular overdenture should be the minimum standard offered to an edentulous patient [3].

In order to further simplify both the treatment plan and surgical procedures and reduce costs for patients in developing countries [36] the concept of a single-implant retained overdenture has been proposed for the mandible [37]. Based on a recent systematic review and meta-analysis there are no differences between one and two implant supported overdentures regarding prosthetic complications, oral health related quality of life and marginal bone loss after five years in function [38]. According to the same authors this treatment modality has the potential to become the new minimum standard.

On the other hand, innovative technologies and materials have been incorporated into the implant supported overdenture fabrication protocol. Obtaining a virtual version of the patient [39] is nowadays feasible due to the synergic utilization an superimposition of both intraoral [40] and facial scanners [41] and cone beam computed tomography [42] via special softwares. These softwares simplify the procedures of treatment plan and design of appliances such as surgical templates [43] that aid during implant placement or replicas for the confirmation of the impression accuracy and can be fabricated either by milling or 3D printing techniques.

At the time being literature does not support the use of intraoral scanners in completely edentulous patients [44]. However, these data are based on first generation scanners while the technologies evolve with a rapid pace and different intraoral scanners perform differently in terms of accuracy. [45] Some recently published studies have reported fabrication of bars for implant supported overdentures with the combination of intraoral scanners and CAD/CAM technologies [46].

New technologies have also made possible the use of materials that are more aesthetic than metal alloys, such as polyether ether ketone (PEEK). PEEK is a biocompatible, non-allergic, rigid, radiolucent, white polymer with low plaque affinity [47] and elastic modulus that is close to human bone [48]. Some recent studies have reported on the use of PEEK as a bar fabrication material with promising results [39] that must be further investigated. Another aesthetic material incorporated in many dental application is zirconia[49], a biocompatible ceramic material with wear resistance and high mechanical properties. According to a crossover study patient satisfaction was superior with zirconia than cobalt-chromium bars in terms of psychological preference, appearance, time, hygiene, undergo procedures, recommend procedures and the overall experience [50].

4. CONCLUSION

Several concerns arise when choosing an implant supported overdenture that mainly refer to the special characteristics defining its function. The key element is the careful preoperative planning of the restoration since it affects the long-term behavior of the prosthesis in terms of technical and biological complications and the frequency of the clinicians reinterventions.

REFERENCES

1. Geckili O, Bilhan H, Mumcu E, Dayan C, Yabul A, Tuncer N. Comparison of patient satisfaction, quality of life, and bite force between elderly edentulous patients wearing mandibular two implant-supported overdentures and conventional complete dentures after 4 years. *Spec Care Dentist*. Jul-Aug 2012;32(4):136-41. doi:10.1111/j.1754-4505.2012.00258.x
2. Azar R, Semyari H, Kharazifard MJ. Oral Health Related Quality of Life of Patients Using Conventional Dentures versus Implant-Supported Overdentures. *Front Dent*. Feb 2020;17(4):1-7. doi:10.18502/fid.v17i1.3964

3. Feine JS, Carlsson GE, Awad MA, et al. The McGill consensus statement on overdentures. Mandibular two-implant overdentures as first choice standard of care for edentulous patients. Montreal, Quebec, May 24-25, 2002. *Int J Oral Maxillofac Implants*. Jul-Aug 2002;17(4):601-2.
4. Jemt T, Chai J, Harnett J, et al. A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. *Int J Oral Maxillofac Implants*. May-Jun 1996;11(3):291-8.
5. Kent G, Johns R. Effects of osseointegrated implants on psychological and social well-being: a comparison with replacement removable prostheses. *Int J Oral Maxillofac Implants*. Jan-Feb 1994;9(1):103-6.
6. Boerrigter EM, Geertman ME, Van Oort RP, et al. Patient satisfaction with implant-retained mandibular overdentures. A comparison with new complete dentures not retained by implants--a multicentre randomized clinical trial. *Br J Oral Maxillofac Surg*. Oct 1995;33(5):282-8. doi:10.1016/0266-4356(95)90038-1
7. Kapur KK, Garrett NR, Hamada MO, et al. Randomized clinical trial comparing the efficacy of mandibular implant-supported overdentures and conventional dentures in diabetic patients. Part III: comparisons of patient satisfaction. *The Journal of prosthetic dentistry*. Oct 1999;82(4):416-27. doi:10.1016/s0022-3913(99)70028-4
8. Thomason JM, Feine J, Exley C, et al. Mandibular two implant-supported overdentures as the first choice standard of care for edentulous patients--the York Consensus Statement. *British dental journal*. Aug 22 2009;207(4):185-6. doi:10.1038/sj.bdj.2009.728
9. Gotfredsen K, Holm B. Implant-supported mandibular overdentures retained with ball or bar attachments: a randomized prospective 5-year study. *The International journal of prosthodontics*. Mar-Apr 2000;13(2):125-30.
10. Mericske-Stern R. Treatment outcomes with implant-supported overdentures: clinical considerations. *The Journal of prosthetic dentistry*. Jan 1998;79(1):66-73. doi:10.1016/s0022-3913(98)70196-9
11. Feine JS, Maskawi K, de Grandmont P, Donohue WB, Tanguay R, Lund JP. Within-subject comparisons of implant-supported mandibular prostheses: evaluation of masticatory function. *Journal of dental research*. Oct 1994;73(10):1646-56. doi:10.1177/00220345940730101001
12. Dimililer G, Kucukkurt S, Cetiner S. Biomechanical effects of implant number and diameter on stress distributions in maxillary implant-supported overdentures. *The Journal of prosthetic dentistry*. Feb 2018;119(2):244-249 e6. doi:10.1016/j.prosdent.2017.03.016
13. Raghoebar GM, Meijer HJ, Slot W, Slater JJ, Vissink A. A systematic review of implant-supported overdentures in the edentulous maxilla, compared to the mandible: how many implants? *Eur J Oral Implantol*. Summer 2014;7 Suppl 2:S191-201.
14. Sadowsky SJ, Zitzmann NU. Protocols for the Maxillary Implant Overdenture: A Systematic Review. *Int J Oral Maxillofac Implants*. 2016;31 Suppl:s182-91. doi:10.11607/jomi.16suppl.g5.2
15. Anadioti E, Gates WD, 3rd, Elpers J, De Kok IJ, Cooper LF. Retrospective cohort analysis of maxillary overdentures retained by unsplinted implants. *The Journal of prosthetic dentistry*. Sep 2019;122(3):301-308 e1. doi:10.1016/j.prosdent.2018.10.014
16. El Mekawy N, Elhawary MY. Clinical evaluation of inter-implant distance influence on the wear characteristics of low-profile stud attachments used in mandibular implantretained overdentures. *J Clin Exp Dent*. Jan 2019;11(1):e33-e41. doi:10.4317/jced.55433
17. Savabi O, Nejatidanesh F, Yordshahian F. Retention of implant-supported overdenture with bar/clip and stud attachment designs. *J Oral Implantol*. Apr 2013;39(2):140-7. doi:10.1563/AAID-JOI-D-11-00016
18. AbuJamra NF, Stavridakis MM, Miller RB. Evaluation of interarch space for implant restorations in edentulous patients: a laboratory technique. *Journal of prosthodontics : official journal of the American College of Prosthodontists*. Jun 2000;9(2):102-5. doi:10.1111/j.1532-849x.2000.00102.x
19. Trakas T, Michalakis K, Kang K, Hirayama H. Attachment systems for implant retained overdentures: a literature review. *Implant Dent*. Mar 2006;15(1):24-34. doi:10.1097/01.id.0000202419.21665.36
20. Carpentieri J, Greenstein G, Cavallaro J. Hierarchy of restorative space required for different types of dental implant prostheses. *Journal of the American Dental Association*. Aug 2019;150(8):695-706. doi:10.1016/j.adaj.2019.04.015

21. Phillips K, Wong KM. Space requirements for implant-retained bar-and-clip overdentures. *Compend Contin Educ Dent*. Jun 2001;22(6):516-8, 520, 522.
22. MA EL, Dayekh MA, Khalifa AK. Locator Versus Bar Attachment Effect on the Retention and Stability of Implant-Retained Maxillary Overdenture: An In Vitro Study. *Journal of prosthodontics : official journal of the American College of Prosthodontists*. Feb 2019;28(2):e627-e636. doi:10.1111/jopr.12608
23. Schneider AL, Kurtzman GM. Bar overdentures utilizing the Locator attachment. *General dentistry*. Mar-Apr 2001;49(2):210-4.
24. Naert I, Gizani S, Vuylsteke M, Van Steenberghe D. A 5-year prospective randomized clinical trial on the influence of splinted and unsplinted oral implants retaining a mandibular overdenture: prosthetic aspects and patient satisfaction. *Journal of oral rehabilitation*. Mar 1999;26(3):195-202. doi:10.1046/j.1365-2842.1999.00369.x
25. Bhakta S, Vere J, Calder I, Patel R. Impressions in implant dentistry. *British dental journal*. Oct 21 2011;211(8):361-7. doi:10.1038/sj.bdj.2011.862
26. Moreira AH, Rodrigues NF, Pinho AC, Fonseca JC, Vilaca JL. Accuracy Comparison of Implant Impression Techniques: A Systematic Review. *Clin Implant Dent Relat Res*. Oct 2015;17 Suppl 2:e751-64. doi:10.1111/cid.12310
27. Kavadia V, Kourtis S, Zoidis P, Sarafianou A. The influence of impression coping splinting on the accuracy of the open-tray technique. *General dentistry*. May-Jun 2019;67(3):e5-e9.
28. Ozcelik TB, Yilmaz B. A functional open-tray impression technique for implant-retained overdenture prostheses. *J Oral Implantol*. Oct 2012;38(5):617-9. doi:10.1563/AAID-JOI-D-10-00159
29. Bidez MW, Chen Y, McLoughlin SW, English CE. Finite element analysis of four-abutment Hader bar designs. *Implant Dent*. Fall 1993;2(3):171-6. doi:10.1097/00008505-199309000-00005
30. Schmidt MB, Rauch A, Schwarzer M, Lethaus B, Hahnel S. Combination of Digital and Conventional Workflows in the CAD/CAM-Fabrication of an Implant-Supported Overdenture. *Materials (Basel)*. Aug 20 2020;13(17)doi:10.3390/ma13173688
31. Spies BC, Petsch M, Kohal RJ, Beuer F. Digital Production of a Zirconia, Implant-Supported Removable Prosthesis with an Individual Bar Attachment Milled from Polyether Ether Ketone: A Case History Report. *The International journal of prosthodontics*. Sep/Oct 2018;31(5):471-474. doi:10.11607/ijp.5866
32. Cakarer S, Can T, Yaltirik M, Keskin C. Complications associated with the ball, bar and Locator attachments for implant-supported overdentures. *Med Oral Patol Oral Cir Bucal*. Nov 1 2011;16(7):e953-9. doi:10.4317/medoral.17312
33. Chee W, Jivraj S. Treatment planning of the edentulous mandible. *British dental journal*. Sep 23 2006;201(6):337-47. doi:10.1038/sj.bdj.4814041
34. Visser A, Raghoebar GM, Meijer HJ, Vissink A. Implant-retained maxillary overdentures on milled bar suprastructures: a 10-year follow-up of surgical and prosthetic care and aftercare. *The International journal of prosthodontics*. Mar-Apr 2009;22(2):181-92.
35. Vogel R, Smith-Palmer J, Valentine W. Evaluating the health economic implications and cost-effectiveness of dental implants: a literature review. *Int J Oral Maxillofac Implants*. Mar-Apr 2013;28(2):343-56. doi:10.11607/jomi.2921
36. Walton JN, MacEntee MI, Hanvelt R. Cost analysis of fabricating implant prostheses. *The International journal of prosthodontics*. May-Jun 1996;9(3):271-6.
37. Cordioli G, Majzoub Z, Castagna S. Mandibular overdentures anchored to single implants: a five-year prospective study. *The Journal of prosthetic dentistry*. Aug 1997;78(2):159-65. doi:10.1016/s0022-3913(97)70120-3
38. Alqutaibi AY, Esposito M, Algabri R, et al. Single vs two implant-retained overdentures for edentulous mandibles: a systematic review. *Eur J Oral Implantol*. 2017;10(3):243-261.
39. Mangano C, Luongo F, Migliario M, Mortellaro C, Mangano FG. Combining Intraoral Scans, Cone Beam Computed Tomography and Face Scans: The Virtual Patient. *The Journal of craniofacial surgery*. Nov 2018;29(8):2241-2246. doi:10.1097/SCS.0000000000004485
40. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the current literature. *BMC Oral Health*. Dec 12 2017;17(1):149. doi:10.1186/s12903-017-0442-x
41. Hassan B, Greven M, Wismeijer D. Integrating 3D facial scanning in a digital workflow to CAD/CAM design and fabricate complete dentures for immediate total mouth rehabilitation.

The journal of advanced prosthodontics. Oct 2017;9(5):381-386. doi:10.4047/jap.2017.9.5.381
42. Jacobs R, Salmon B, Codari M, Hassan B, Bornstein MM. Cone beam computed tomography in implant dentistry: recommendations for clinical use. *BMC Oral Health*. May 15 2018;18(1):88. doi:10.1186/s12903-018-0523-5
43. Joda T, Derksen W, Wittneben JG, Kuehl S. Static computer-aided implant surgery (s-CAIS) analysing patient-reported outcome measures (PROMs), economics and surgical complications: A systematic review. *Clinical oral implants research*. Oct 2018;29 Suppl 16:359-373. doi:10.1111/clr.13136
44. Di Fiore A, Meneghello R, Graiff L, et al. Full arch digital scanning systems performances for implant-supported fixed dental prostheses: a comparative study of 8 intraoral scanners. *Journal of prosthodontic research*. Oct 2019;63(4):396-403. doi:10.1016/j.jpor.2019.04.002
45. Imburgia M, Logozzo S, Hauschild U, Veronesi G, Mangano C, Mangano FG. Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study. *BMC Oral Health*. Jun 2 2017;17(1):92. doi:10.1186/s12903-017-0383-4
46. Gherlone E, Cappare P, Vinci R, Ferrini F, Gastaldi G, Crespi R. Conventional Versus Digital Impressions for "All-on-Four" Restorations. *Int J Oral Maxillofac Implants*. Mar-Apr 2016;31(2):324-30. doi:10.11607/jomi.3900
47. Najeeb S, Zafar MS, Khurshid Z, Siddiqui F. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. *Journal of prosthodontic research*. Jan 2016;60(1):12-9. doi:10.1016/j.jpor.2015.10.001
48. Garcia-Gonzalez D, Jayamohan J, Sotiropoulos SN, et al. On the mechanical behaviour of PEEK and HA cranial implants under impact loading. *J Mech Behav Biomed Mater*. May 2017;69:342-354. doi:10.1016/j.jmbbm.2017.01.012
49. Zhang Y, Lawn BR. Novel Zirconia Materials in Dentistry. *Journal of dental research*. Feb 2018;97(2):140-147. doi:10.1177/0022034517737483
50. Altonbary GY, Emera RMK. Patient satisfaction and masticatory performance of zirconia bar compared to cobalt chromium bar retaining mandibular implant overdenture: A crossover study. *Journal of oral rehabilitation*. Jul 2021;48(7):827-835. doi:10.1111/joor.13164