We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,300

Open access books available

172,000

International authors and editors

190M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Implant-Retained Maxillary and Mandibular Overdentures - A Solution for Completely Edentulous Patients

Dubravka Knezović Zlatarić, Robert Ćelić and Hrvoje Pezo

Abstract

The main goal of modern removable prosthodontics is to restore the normal appearance, function, esthetics and speech in each completely edentulous patient. However, if all teeth are missing in a patient, it becomes very complicated to achieve it using traditional protocols. Therefore, implants were introduced into removable prosthodontics to ensure better retention and stability of the conventional dentures. In case of a large amount of bone missing in the jaw it is necessary to ensure the functioning of the dentures constructing various additional stabilizing and retentive prosthodontic solutions on the osseointegrated implants. Numerous types of attachment systems have been used recently for relating implant-retained overdentures to underlying implants: basically splinting (various bar shape designs) and non-splinting attachments (various ball type attachment, magnet attachment, telescopic coping systems). Indications for their use depend on the surgical and prosthodontic factors such as the number and position of the implants, the amount of free intermaxillary space and the type and size of the overdentures. Different indications, types of the overdentures and the attachment systems will be discussed in this chapter.

Keywords: edentulous patient, implant-retained overdenture, bar shape attachment, ball type attachment, telescopic coping attachment, retention, stability

1. Introduction

Edentulism is defined as an irreversible condition in the patient's mouth and the "final marker of disease burden for oral health" [1, 2]. It is still one of the major problems among older adults globally, regardless of its declining incidence. The prevalence of complete edentulism varies among different countries all around the world since it depends on numerous factors such as education, economic and social situations, lifestyle, oral and general health knowledge and views, and attitudes to dental care [3, 4]. The rate of edentulism tends to vary not only among different countries but among different regions within a country too, with wealthier, more industrialized provinces tending to have lower rates than others [5]. A large number of studies confirm the close relationship between edentulism and age and gender of the patients, their educational and income

level, activities of daily living, social isolation and poor self-experienced health [6, 7]. These findings should be recognized at the national level of each country and used to create preventive measures identifying older people who are in need of oral care.

2. Aging - tooth loss - bone loss

Edentulous patients are in need of wearing some kind of prosthodontic replacement to establish lost oral function caused by tooth loss. It occurs because of biologic disease processes and age-related changes, such as dental caries, trauma, periodontal conditions and diseases, as well as poor oral hygiene and oral cancer [8, 9]. Total tooth loss is not only reflected in patients' inability to chew and speak but to their social behavior and self-image and it has a complex and multidimensional impact on oral health related and general quality of life [10, 11].

A large number of studies have already proven that bone loss represents an ongoing process following tooth loss [12, 13], affecting the mandible four times more than the maxilla [14]. This particularly affects the patients who become completely edentulous and creates a large problem for their future maintenance (**Figure 1**).

For the purpose of better understanding of the existing conditions, analysis of the edentulous jaws, easier diagnosis and therapy determination the American College of Prosthodontists (ACP) has developed a classification system for complete edentulism helping prosthodontists determine appropriate treatments for their edentulous patients [15]. This classification consists of four categories, the first representing an uncomplicated clinical situation with ideal or minimally compromised bone height, inter-jaw relationship, residual ridge morphology and muscle attachments and the fourth, representing the most complex and severely compromised oral conditions significantly negatively affecting the prosthodontic outcome [16].

Figure 1.
Current condition of the edentulous maxilla and mandible caused by years of toothlessness. The height of the frontal mandibular bone has been measured to evaluate the possibility of implant placement.

3. Prosthodontic solutions in completely edentulous patients

Toothless residual alveolar ridges in edentulous patients imply the construction of retentive and stable conventional complete dentures [17]. Unfortunately, this can only

be achieved in favorable oral conditions that mostly apply to the satisfactory edentulous ridge form and height affecting stability and retention of the dentures in function [18, 19]. It has already been proved that ill-fitting conventional complete dentures can compromise patient's oral function and therefore cause psychosocial problems and decrease his/her oral health-related quality of life (OHRQoL) [20, 21]. The most often recorded complains among conventional complete denture wearers are pure or fair chewing ability, mostly within the subjects who had lost more than 50% of their estimated original ridge height, correlating the residual ridge resorption with worsening of the complete denture stability during mastication [22, 23].

4. Implant prosthodontics

In the last few decades, implants have been increasingly introduced in prosthodontics to replace patient's tooth/teeth lost for several reasons including trauma, caries, and periodontal disease as one of the main causes of edentulism occurring in the elderly population [24]. The loss of single, several or even all the teeth in the jaws can be compensated by placing one or more implants and constructing fixed or removable prosthodontic restorations on them [25–30].

A large number of risk factors related to the implant-prosthodontic therapy are listed in the literature, both at the level of implants as well as of implant prosthodontic restorations [31–34]. It has already been proved in many studies that poorer bone quality and lack of bone volume may be the one of the main reasons of implant failure [35]. Therefore, numerous classifications assisting the therapist in determination of the proper implant-prosthodontic therapy have been suggested for assessment of the degree of atrophy of edentulous jaws, among which the classification system for jaw bone shape and quality proposed by Lekholm and Zarb in 1985 is very often used [36]. One of the major problems in elderly population certainly is the lack and poorer quality of bone structure (Lekholm and Zarb quality 3 or 4 and quantity C, D, or E), especially in the distal part of the alveolar ridges, offering a great challenge for the placement of multiple implants or immediate implant loading and fixed implant prosthodontic constructions [37, 38]. Therefore, in these patients, having compromised bone conditions, implant-retained overdentures may be the best solution [39].

5. McGill consensus statement on overdentures

With an increase of the life expectancy in the following years an increased number of completely edentulous patients will visit dental offices [40]. With a higher standards of their life quality they will expect the same level of standards in prosthodontic treatments demanding improvement in the oral health quality of life, too [40]. With conventional complete dentures relying upon resorbed residual bone ridges of maxilla and mandible and overlying mucosal soft tissues satisfactory retention and stability of the dentures is usually not possible to achieve. Therefore, it is up to the prosthodontics to find new solutions to this issue.

In May 2002, at McGill University in Montreal, Canada, prosthodontic symposium was held where numerous relevant experts who worked in the field of removable prosthodontics stated that the current available evidence suggested the restoration of the completely edentulous mandible using conventional complete denture is no longer the first choice in prosthodontic treatments and instead it should be a

two-implant overdenture, regardless of the type of attachment system used (bar, ball or magnet) [41, 42]. According to the available literature patients find mandibular implant-retained overdentures to be superior over conventional ones in retention, ability to chew and speak, comfort, and satisfaction and in oral health related quality of life [43–46]. In April 2009. In York, UK a further consensus statement created by members of British Society for the Study of Prosthetic dentistry Council was released highlighting that uptake by dentists of implants for completely edentulous patients has still been rather slow [47].

As it is stated in the Consensus Statement, the solution in completely edentulous patient should be maxillary conventional complete denture and mandibular two implant-retained overdenture and this therapy presents a minimum standard that should be sufficient for the most patients, taking into account patient comfort and satisfaction, costs and both clinical and dental laboratory time [41, 47]. According to the Statement, placement of only two implants increases the total cost of the treatment, but it is still low enough (in comparison to the multiple implant-prosthetic restorations) to be affordable to most edentulous patients [41].

6. Prosthodontic indications and advantages for implant supported overdenture in completely edentulous patients

A large number of completely edentulous patients wearing conventional complete dentures are dissatisfied with their prosthodontic restorations [48]. Therefore, implant-retained overdentures were introduced to fulfill a need for maximum support

Figure 2.
Three-dimensional measurement of maxillary bone in completely edentulous patient. Notice the extreme resorption of the whole maxillary residual arch.

in edentulous dental arches together with the desire to improve esthetic appearance [49]. Consequently, they are indicated in patients suffering from severe morphological destruction of denture supporting regions with significant loss of denture retention and stability (**Figures 2 and 3**), those with poor oral muscular coordination and low

Figure 3.
Three-dimensional measurement of mandibular bone in completely edentulous patient. The resorption of the mandibular residual arch is not so progressive, therefore the placement of 4 implants in the frontal region is indicated.

Figure 4.
Vestibular view of 2 implant-retained mandibular overdenture.

tolerance of soft underlying tissues, having parafunctional habits increasing soreness and instability of the conventional restorations or severe gag reflexes [50].

This type of removable prosthodontic rehabilitation is also strongly recommended in patients with unrealistic conventional prosthodontic expectations and those having psychological problems in wearing removable dentures, even when adequate retention and stability are present in the function [50].

This type of implant-prosthodontic rehabilitation offers several advantages such as need for less implants resulting in lower component costs and less expensive treatments for the patient, easy handling and home care maintenance, achieving extremely high level of facial esthetics by labial acrylic flanges and denture teeth replacing missing bone structure and avoiding parafunctions by removing dentures at night (**Figures 4 and 5**).

The results of the trial reported in Feine et al. and Grandmont et al. suggested that many patients having the chance to compare both fixed and removable

Figure 5.
Oral view of 2 implant-retained mandibular overdenture.

Figure 6.
Individual tray, functional impression and laboratory analogs for 4 implant-retained mandibular overdenture.

implant-supported mandibular prostheses considered removable types to be a first class treatment [51, 52]. Half of the primarily older individuals monitored in this trial preferred removable over fixed prostheses for easier cleaning and ability to take them out during the night, but reported to be less efficient for chewing [51, 52]. Therefore, this finding should be used by clinicians when choosing the most appropriate type of dentures in completely edentulous patients, too.

It is also important to mention that both clinical and dental laboratory procedures when fabricating implant-retained maxillary and mandibular overdentures do not differ significantly from the conventional on, with the exception of the use of implant transfers, laboratory analogs and individually adjusted trays (Figures 6–8).

Figure 7.
Open acrylic individual tray and implant transfers ready for impression.

Figure 8.
Both vertical and horizontal dimension registration of the future maxillary conventional and 4 implant-retained mandibular overdenture using wax rims.

7. Number of implants in implant-retained overdentures

Implant-retained overdentures are usually indicated in completely edentulous cases with mild to severe bone resorption in certain regions and therefore go with reduced number of implants. The minimum number of implants needed for an overdenture is still in debate.

According to the literature in case of maxillary overdenture with both implant and soft tissue support four to six implants are needed for retention and stability [53–55]. In case of four implants reduction in palatal plate of the denture is reported and recommended (**Figures 9 and 10**) [56, 57].

There are many reports in literature on two implant-retained overdentures in maxilla, too, but it is still the subject of debates (**Figure 11**).

Figure 9.
Four dental implants in maxilla. Clinical procedure of adjusting locators in 4 implant-retained maxillary overdenture.

Figure 10.
Distal reduction of the 4 implant-retained maxillary overdenture palatal plate.

Figure 11.

Clinical check-up of the patient five years following the placement of two implants in maxilla and delivery of the 2 implant-retained maxillary overdenture.

Klemetti et al. concluded that using only two implants in the maxilla did not compromise the dentures longevity or patient satisfaction when compared with four implant overdentures on one hand, but many authors claim that this design of implant-retained overdenture may result in a hinging movement and cause discomfort [58–60].

In mandible, in case of overdenture with both implant and soft tissue support, two implants supported overdenture or single implant retained overdenture is also advisable [61–64].

8. Types of attachment systems on implant-retained overdentures

According to The McGill Consensus Statement on overdentures mandibular two-implant overdentures (**Figure 12**) are considered to be the first choice standard of care for edentulous patients regardless of the type of attachment system used [41].

Numerous types of attachment systems supporting implant overdentures have been developed over years, such as bars, balls, magnets, different cylindrical attachments etc., made of different materials, according to different concepts and designs [65–71].

Figure 12.

Standard implant-prosthetic procedure in completely edentulous patient according to the McGilly consensus.

Of the previously listed systems, only bars require mechanically constructed splinting of the implants and the need to connect them via rigid construction or not is still being discussed.

Both splinted and unsplinted overdenture implant attachment systems have unique advantages and disadvantages. Although different in construction, it seems that both systems achieve similar results with regard to marginal bone loss, prosthetic complications and implant survival rate [72]. A systematic research, carried out from 2000. to 2018., investigated the influence of splinted vs. unsplinted designs for 4 implants retained maxillary overdentures in terms of the outcome assessed in implant survival, prosthodontic longevity and patients' satisfaction. The results revealed no influence of the overdenture design on survival rates of both implants and dentures, as well as on patients' satisfaction with implant survival rate higher than 97%, overdenture survival rate of 100% and patients' satisfaction scores higher than 4.5 (on a 1 to 5 Likert scale) for general satisfaction, chewing ability, denture stabilization, esthetic results and speech [73].

Location of the implants in the edentulous jaw serving for the retention and stability of the overdenture as well as each edentulous arch shape highly influence the stress concentration and distribution around the implants and denture bearing area [74, 75].

If it is about splinted overdenture implant attachment systems using bars made from different materials polyetheretherketone (PEEK), titanium and Co-Cr alloys) the question of designing additional distal cantilever arises. Numerous authors confirmed that, if used, the length of the cantilever should not exceed the anteroposterior span length, with most commonly mentioned length from 7 to 12 mm (**Figure 13**) [76, 77].

Although it has already been proven that cantilevering of the bars in this type of implant prosthodontic restoration may increase bone loss around supporting implants, especially around the implant adjacent to cantilever, without cantilevers there is less retention and stability of the dentures in the function [78–80]. However, not only does the cantilever and its length cause the problems with loss of bone structure around the implants, but increase in bar height can increase stress levels on the peri-implant crestal bone, too [81].

Figure 13.
Splinted 4 implant-retained maxillary overdenture with short distal cantilevers.

From the technical point of view, unsplinted overdenture implant attachment systems such as Locators, balls or magnets are much easier to construct, provide more prosthodontic space and require up to 1 cm vertical space for the attachments (**Figures 14–16**) [82, 83].

Figure 14.
Radiological assessment of implant osseointegration prior to the delivery of 4 implant-retained mandibular overdenture.

Figure 15.
Stone casts with laboratory analogs indicating the position of the locators in the edenetulous mandible.

Figure 16.
Titanium housings on the laboratory analogs.

9. Prosthodontic maintenance of different implant-retained overdentures

Prosthetic complications with implant-retained overdentures are unavoidable and are mostly mechanical [84]. Compared with conventional complete dentures there is a higher rate of repair and replacement of this type of dentures, mostly regarding their design and type of the attachment system [84].

In cases where implant retained overdenture is not reinforced by the metal framework higher rate of acrylic fractures must be expected, especially in the cases where the matrix size of the attachment system is relatively too large [85].

Different attachment systems require different care. It has been proven that rigid bars connecting 4 implants show lower incidence rate of maintenance such as clip activation or resolving the fracture, than resilient system such as round bars most likely because of its inability to rotate around the fulcrum line during the function [86]. The data also demonstrates an increase in prosthodontic maintenance for ball attachments related to the wear or fracture of the ball head or need for activation of the ball matrix or relining of the denture [87, 88].

Numerous authors reported different types of matrix repairs, too, such as clip fractures or clip activation in the period of 5 years, most commonly in the first year [89, 90].

Furthermore, the longevity of the implant retained overdenture depends on maintaining oral and denture hygiene, as well as frequency of use. It is clear that simpler constructions, away from mucosa, are easier to maintain and clean, such as balls and locators in comparison to the bars, especially if they are in the close relationship with the mucosa [91]. Nocturnal use of this type of dentures has also showed higher

Figure 17.
4 implant-retained maxillary overdenture follow-up protocol.

incidence of stomatitis due to the excellent retention, less saliva produced and more bacteria to develop in that environment [92].

It is necessary to emphasize that the prosthodontic complications can be reduced to an expected level if a close follow-up protocol is applied (**Figures 17 and 18**).

Figure 18.
4 implant-retained mandibular overdenture follow-up protocol.

Figure 19.
Appearance of 4 implant-retained maxillary and mandibular overdentures - frontal and both lateral views.

Figure 20.

Portrait view of the patient with 4 implant-retained maxillary and mandibular overdentures in occlusion and in smile.

We must also not forget that ultimate goal of producing implant-retained overdentures is patient's satisfaction not only with the esthetics but also with the long-term function of the removable prosthodontic restoration (**Figures 19 and 20**).

10. Conclusion

Implant-retained overdentures are very attractive implant-prosthodontic treatment because of its relative simplicity in construction and design, easy handling, minimal invasiveness and lower costs. They are particularly suitable to maintain facial support and achieve higher level of esthetics with denture acrylic material when moderate to extreme alveolar ridge resorption is present in patient's mouth, mainly in the older population. It is very important to emphasize that the implant-retained overdentures are supported by both implants and denture underlying soft tissue and therefore fewer implants are requested compared to the prosthodontic restorations supported only by implants.

This type of overdenture is usually connected with two or four implants, depending on which jaw is involved and on quality and quantity of the residual bone structure. These implants are mainly placed within the alveolar bone on the opposite sides of the completely edentulous arch and connected to the complete denture using different correspondent coupling units placed on the tissue surface of the prosthodontic restoration. When implant and denture attachments are appropriately connected, the complete denture is held in position over the denture bearing area and both implants and mucosa provide support, retention and stability in function. The main advantage of this type of implant-prosthodontic solution over fixed one is that the implant-retained overdenture can be easily removed and cleaned (easy access to both the denture and the implants'

abutments) and therefore provides better oral hygiene and may affect greater longevity of the restoration itself.

The results of this systematic review indicate the superiority of implant-retained overdentures when compared to conventional complete dentures in fully edentulous patients suffering from moderate to severe alveolar bone resorption with regards to efficacy, patients' satisfaction and quality of their life.

Notes

All the cases presented in this chapter were patients from Dental Polyclinic Ars Salutaris, Zagreb, Croatia, and the laboratory work was done in Naturaldent dental laboratory, Zagreb, Croatia.

Author details

Dubravka Knezović Zlatarić^{1*}, Robert Ćelić¹ and Hrvoje Pezo²

1 Department of Removable Prosthodontics, School of Dental Medicine, University of Zagreb, Zagreb, Croatia

2 Dental Polyclinic Ars Salutaris, Zagreb, Croatia

*Address all correspondence to: knezovic@sfzg.hr

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

- [1] Cunha-Cruz J, Hujoel PP, Nadanovsky P. Secular trends in socio-economic disparities in edentulism: USA, 1972-2001. *J Dent Res*. 2007;86 (2):131-6. DOI: 10.1177/154405910708600205.
- [2] Emami E, de Souza RF, Kabawat M, Feine JS. The impact of edentulism on oral and general health. *Int J Dent*. 2013;2013:498305. DOI: 10.1155/2013/498305.
- [3] Müller F, Naharro M, Carlsson GE. What are the prevalence and incidence of tooth loss in the adult and elderly population in Europe? *Clin Oral Implants Res*. 2007;18 Suppl 3:2-14. DOI: 10.1111/j.1600-0501.2007.01459.x.
- [4] Douglass CW, Shih A, Ostry L. Will there be a need for complete dentures in the United States in 2020? *J Prosthet Dent*. 2002;87(1):5-8. DOI: 10.1067/mpr.2002.121203.
- [5] Kailembo A, Preet R, Stewart Williams J. Common risk factors and edentulism in adults, aged 50 years and over, in China, Ghana, India and South Africa: results from the WHO Study on global AGEing and adult health (SAGE). *BMC Oral Health*. 2016;27;17(1):29. doi: 10.1186/s12903-016-0256-2.
- [6] Olofsson H, Ulander EL, Gustafson Y, Hörnsten C. Association between socioeconomic and health factors and edentulism in people aged 65 and older - a population-based survey. *Scand J Public Health*. 2018;46(7):690-8. DOI: 10.1177/1403494817717406.
- [7] Roberto LL, Crespo TS, Monteiro-Junior RS, Martins AMEBL, De Paula AMB, Ferreira EF, et al. Sociodemographic determinants of edentulism in the elderly population: A systematic review and meta-analysis. *Gerodontology*. 2019;36(4):325-37. DOI: 10.1111/ger.12430.
- [8] Lee DJ, Saponaro PC. Management of Edentulous Patients. *Dent Clin North Am*. 2019;63(2):249-61. DOI: 10.1016/j.cden.2018.11.006.
- [9] Balic A. Biology Explaining Tooth Repair and Regeneration: A Mini-Review. *Gerontology*. 2018;64(4):382-88. DOI: 10.1159/000486592.
- [10] Peyron MA, Woda A, Bourdiol P, Hennequin M. Age-related changes in mastication. *J Oral Rehabil*. 2017;44(4):299-312. DOI: 10.1111/joor.12478.
- [11] Alves AC, Cavalcanti RV, Calderon PS, Pernambuco L, Alchieri JC. Quality of life related to complete denture. *Acta Odontol Latinoam*. 2018;31(2):91-6.
- [12] Lombardi T, Bernardello F, Berton F, Porrelli D, Rapani A, Camurri Piloni A, et al. Efficacy of Alveolar Ridge Preservation after Maxillary Molar Extraction in Reducing Crestal Bone Resorption and Sinus Pneumatization: A Multicenter Prospective Case-Control Study. *Biomed Res Int*. 2018;2018:9352130. DOI: 10.1155/2018/9352130.
- [13] Rahim-Wöstefeld S, El Sayed N, Weber D, Kaltschmitt J, Bäumer A, El-Sayed S, et al. Tooth-related factors for tooth loss 20 years after active periodontal therapy-A partially prospective study. *J Clin Periodontol*. 2020;47(10):1227-36. doi: 10.1111/jcpe.13348.
- [14] Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal

study covering 25 years. *J Prosthet Dent.* 1972; 27(2):120-32.

[15] McGarry TJ, Nimmo A, Skiba JF, Ahlstrom RH, Smith CR, Koumjian JH. Classification system for complete edentulism. *The American College of Prosthodontics. J Prosthodont.* 1999;8(1):27-39. DOI: 10.1111/j.1532-849x.1999.tb00005.x.

[16] Mazurat RD, Mazurat NM. Communicating complexity: using a diagnostic classification system for edentulous patients. *J Can Dent Assoc.* 2003;69(8):511-4.

[17] Fitzpatrick B. Standard of care for the edentulous mandible: a systematic review. *J Prosthet Dent.* 2006;95(1):71-8. DOI: 10.1016/j.prosdent.2005.11.007.

[18] Yamaga E, Sato Y, Minakuchi S. A structural equation model relating oral condition, denture quality, chewing ability, satisfaction, and oral health-related quality of life in complete denture wearers. *J Dent.* 2013;41(8):710-7. DOI: 10.1016/j.jdent.2013.05.015.

[19] Canger EM, Celenk P. Radiographic evaluation of alveolar ridge heights of dentate and edentulous patients. *Gerodontology.* 2012;29(1):17-23. DOI: 10.1111/j.1741-2358.2010.00391.x.

[20] Teng CJ, Lin SC, Chen JH, Chen Y, Kuo HC, Ho PS. The association between denture self-satisfaction rates and OHRQoL - a follow-up study. *BMC Oral Health.* 2020;20(1):140. DOI: 10.1186/s12903-020-01119-1.

[21] Yamamoto S, Shiga H. Masticatory performance and oral health-related quality of life before and after complete denture treatment. *J Prosthodont Res.* 2018;62(3):370-4. DOI: 10.1016/j.jpor.2018.01.006.

[22] Närhi TO, Ettinger RL, Lam EW. Radiographic findings, ridge resorption, and subjective complaints of complete denture patients. *Int J Prosthodont.* 1997;10(2):183-9.

[23] Karesvuo P, Gursoy UK, Pussinen PJ, Suominen AL, Huuonen S, Vesti E, et al. Alveolar bone loss associated with age-related macular degeneration in males. *J Periodontol.* 2013;84(1):58-67. DOI: 10.1902/jop.2012.110643.

[24] Clark D, Levin L. In the dental implant era, why do we still bother saving teeth? *Dent Traumatol.* 2019;35(6):368-75. DOI: 10.1111/edt.12492.

[25] Hebel K, Gajjar R, Hofstede T. Single-tooth replacement: bridge vs. implant-supported restoration. *J Can Dent Assoc.* 2000 Sep;66(8):435-8.

[26] Pjetursson BE, Heimisdottir K. Dental implants - are they better than natural teeth? *Eur J Oral Sci.* 2018;126 Suppl 1:81-7. DOI: 10.1111/eos.12543.

[27] Ravidà A, Tattan M, Askar H, Barootchi S, Tavelli L, Wang HL. Comparison of three different types of implant-supported fixed dental prostheses: A long-term retrospective study of clinical outcomes and cost-effectiveness. *Clin Oral Implants Res.* 2019;30(4):295-305. DOI: 10.1111/clr.13415.

[28] Chan MH, Holmes C. Contemporary "All-on-4" concept. *Dent Clin North Am.* 2015;59(2):421-70. DOI: 10.1016/j.cden.2014.12.001.

[29] 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.

- [30] Chen KW, Lin TM, Liu PR, Ramp LC, Lin HJ, Wu CT, Pan YH. An analysis of the implant-supported overdenture in the edentulous mandible. *J Oral Rehabil.* 2013;40(1):43-50. DOI: 10.1111/joor.12010.
- [31] Borba M, Deluiz D, Lourenço EJV, Oliveira L, Tannure PN. Risk factors for implant failure: a retrospective study in an educational institution using GEE analyses. *Braz Oral Res.* 2017;31:e69. DOI: 10.1590/1807-3107BOR-2017.vol31.0069.
- [32] Ramanauskaite A, Becker J, Sader R, Schwarz F. Anatomic factors as contributing risk factors in implant therapy. *Periodontol* 2000. 2019;81(1):64-75. DOI: 10.1111/prd.12284.
- [33] Salvi GE, Bragger U. Mechanical and technical risks in implant therapy. *Int J Oral Maxillofac Implants.* 2009;24 Suppl:69-85.
- [34] Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications with implants and implant prostheses. *J Prosthet Dent.* 2003;90(2):121-32. DOI: 10.1016/S0022-3913(03)00212-9.
- [35] Chrcanovic BR, Albrektsson T, Wennerberg A. Bone Quality and Quantity and Dental Implant Failure: A Systematic Review and Meta-analysis. *Int J Prosthodont.* 2017;30(3):219-37. DOI: 10.11607/ijp.5142.
- [36] Juodzbals G, Kubilius M. Clinical and radiological classification of the jawbone anatomy in endosseous dental implant treatment. *J Oral Maxillofac Res.* 2013;4(2):e2. DOI: 10.5037/jomr.2013.4202.
- [37] Thor A, Ekstrand K, Baer RA, Toljanic JA. Three-year follow-up of immediately loaded implants in the edentulous atrophic maxilla: a study in patients with poor bone quantity and quality. *Int J Oral Maxillofac Implants.* 2014;29(3):642-9. DOI: 10.11607/jomi.3163.
- [38] Bryant SR, Zarb GA. Outcomes of implant prosthodontic treatment in older adults. *J Can Dent Assoc.* 2002;68(2):97-102.
- [39] Mericske-Stern R. Treatment outcomes with implant-supported overdentures: clinical considerations. *J Prosthet Dent.* 1998;79(1):66-73. DOI: 10.1016/s0022-3913(98)70196-9.
- [40] Melescanu Imre M, Marin M, Preoteasa E, Tancu AM, Preoteasa CT. Two implant overdenture--the first alternative treatment for patients with complete edentulous mandible. *J Med Life.* 2011;4(2):207-9.
- [41] Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani S, 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.* 2002;17(4):601-2.
- [42] White GS. Treatment of the edentulous patient. *Oral maxillofac Surg Clin North Am.* 2015;27(2):265-72. DOI: 10.1016/j.coms.2015.01.005.
- [43] Possebon APDR, Schuster AJ, Bielemann AM, Porto BL, Boscato N, Faot F. Evaluation of Bite Force and Masticatory Performance: Complete Denture vs Mandibular Overdenture Users. *Braz Dent J.* 2020;31(4):399-403. DOI: 10.1590/0103-6440202003525.
- [44] Boven GC, Raghoobar GM, Vissink A, Meijer HJ. Improving masticatory performance, bite force, nutritional state and patient's satisfaction

with implant overdentures: a systematic review of the literature. *J Oral Rehabil.* 2015;42(3):220-33. DOI: 10.1111/joor.12241.

[45] Awad MA, Rashid F, Feine JS; Overdenture Effectiveness Study Team Consortium. The effect of mandibular 2-implant overdentures on oral health-related quality of life: an international multicentre study. *Clin Oral Implants Res.* 2014;25(1):46-51. DOI: 10.1111/clr.12205.

[46] Kutkut A, Bertoli E, Frazer R, Pinto-Sinai G, Fuentealba Hidalgo R, Studts J. A systematic review of studies comparing conventional complete denture and implant retained overdenture. *J Prosthodont Res.* 2018;62(1):1-9. DOI: 10.1016/j.jpor.2017.06.004.

[47] Thomason JM, Kelly SA, Bendkowski A, Ellis JS. Two implant retained overdentures--a review of the literature supporting the McGill and York consensus statements. *J Dent.* 2012;40(1):22-34. DOI: 10.1016/j.jdent.2011.08.017.

[48] Allen PF, McMillan AS. The impact of tooth loss in a denture wearing population: an assessment using the Oral Health Impact Profile. *Community Dent Health.* 1999;16(3):176-80.

[49] Bergendal T, Engquist B. Implant-supported overdentures: a longitudinal prospective study. *Int J Oral Maxillofac Implants.* 1998;13(2):253-62.

[50] Rasmussen RA. The Branemark System of Oral Reconstruction: A Clinical Atlas. St. Louis: Ishiyaku EuroAmerica, Inc.;1992.

[51] Feine JS, de Grandmont P, Boudrias P, Brien N, LaMarche C, Taché R, et al. Within-subject comparisons of

implant-supported mandibular prostheses: choice of prosthesis. *J Dent Res.* 1994;73(5):1105-11. DOI: 10.1177/00220345940730051301.

[52] de Grandmont P, Feine JS, Taché R, Boudrias P, Donohue WB, Tanguay R, et al. Within-subject comparisons of implant-supported mandibular prostheses: psychometric evaluation. *J Dent Res.* 1994;73(5):1096-104. DOI: 10.1177/00220345940730051201.

[53] Misch C. *Dental Implant Prosthetics.* 2nd ed. Amsterdam: Elsevier; 2014.

[54] Mericske-Stern R, Oetterli M, Kiener P, Mericske E. A follow-up study of maxillary implants supporting an overdenture: clinical and radiographic results. *Int J Oral Maxillofac Implants.* 2002;17(5):678-86.

[55] Di Francesco F, De Marco G, Capcha EB, Lanza A, Cristache CM, Vernal R, et al. Patient satisfaction and survival of maxillary overdentures supported by four or six splinted implants: a systematic review with meta-analysis. *BMC Oral Health.* 2021;21(1):247. doi: 10.1186/s12903-021-01572-6.

[56] Di Francesco F, De Marco G, Gironi Carnevale UA, Lanza M, Lanza A. The number of implants required to support a maxillary overdenture: a systematic review and meta-analysis. *J Prosthodont Res.* 2019;63(1):15-24. DOI: 10.1016/j.jpor.2018.08.006.

[57] Hegazy SA, El Mekawy N, Emera RMK. Impact of implants number and attachment type on the peri-implant stresses and retention of palateless implant-retained overdenture. *Ind J Dent Res.* 2020;31(3):414-9. DOI: 10.4103/ijdr.IJDR_772_18.

[58] Klemetti E. Is there a certain number of implants needed to retain an

overdenture? J Oral Rehabil. 2008;35 Suppl 1:80-4. DOI: 10.1111/j.1365-2842.2007.01825.x.

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

[60] Kiener P, Oetterli M, Mericske E, Mericske-Stern R. Effectiveness of maxillary overdentures supported by implants: maintenance and prosthetic complications. Int J Prosthodont. 2001;14(2):133-40.

[61] Shah K, Yilmaz B, McGlumphy E. Fabrication of a Mandibular Implant-Supported Overdenture with a New Attachment System: A Review of Current Attachment Systems. Int J Prosthodont. 2017;30(3):245-7. DOI: 10.11607/ijp.5068.

[62] Liu W, Zhang X, Qing H, Wang J. Effect of LOCATOR attachments with different retentive forces on the stability of 2-implant-retained mandibular overdenture. J Prosthet Dent. 2020;124(2):224-9. DOI: 10.1016/j.prosdent.2019.09.005.

[63] Nogueira TE, Dias DR, Leles CR. Mandibular complete denture versus single-implant overdenture: a systematic review of patient-reported outcomes. J Oral Rehabil. 2017;44(12):1004-6. DOI: 10.1111/joor.12550.

[64] Mahoorkar S, Bhat S, Kant R. Single implant supported mandibular overdenture: A literature review. J Indian Prosthodont Soc. 2016;16(1):75-82. DOI: 10.4103/0972-4052.164881.

[65] Kern JS, Kern T, Wolfart S, Heussen N. A systematic review and meta-analysis of removable and fixed implant-supported prostheses in edentulous jaws: post-loading implant

loss. Clin Oral Implants Res. 2016;27(2):174-95. DOI: 10.1111/clr.12531.

[66] Payne AG, Alsabeeha NH, Atieh MA, Esposito M, Ma S, Anas El-Wegoud M. Interventions for replacing missing teeth: attachment systems for implant overdentures in edentulous jaws. Cochrane Database Syst Rev 2018;10(10):CD008001. DOI: 10.1002/14651858.CD008001.pub2.

[67] Matthys C, Vervaeke S, Besseler J, Doornewaard R, Dierens M, De Bruyn H. Five years follow-up of mandibular 2-implant overdentures on locator or ball abutments: Implant results, patient-related outcome, and prosthetic aftercare. Clin Implant Dent Relat Res. 2019;21(5):835-44. DOI: 10.1111/cid.12840.

[68] Takahashi T, Gonda T, Tomita A, Maeda Y. Effect of Attachment Type on Implant Strain in Maxillary Implant Overdentures: Comparison of Ball, Locator, and Magnet Attachments. Part 2: Palateless Dentures. Int J Oral Maxillofac Implants. 2018;33(2):357-64. DOI: 10.11607/jomi.6157.

[69] Ceruti P, Bryant SR, Lee JH, MacEntee MI. Magnet-retained implant-supported overdentures: review and 1-year clinical report. J Can Dent Assoc. 2010;76:a52.

[70] Boven GC, Meijer HJA, Vissink A, Raghoobar GM. Maxillary implant overdentures retained by use of bars or locator attachments: 1-year findings from a randomized controlled trial. J Prosthodont Res. 2020;64(1):26-33. DOI: 10.1016/j.jpor.2019.04.013.

[71] Pisani M, Bedos C, da Silva CHL, Fromentin O, de Albuquerque RF Jr. A Qualitative Study on Patients' Perceptions of Two Types of Attachments for Implant Overdentures. J

Oral Implantol. 2017;43(6):476-81. DOI: 10.1563/aaaid-joi-D-17-00166.

Implants. 2013; 28(3):e143-50. DOI: 10.11607/jomi.2467.

[72] Leão RS, Moraes SLD, Vasconcelos BCE, Lemos CAA, Pellizzer EP. Splinted and unsplinted overdenture attachment systems: A systematic review and meta-analysis. *J Oral Rehabil.* 2018;45(8):647-56. doi: 10.1111/joor.12651.

[78] Bilhan H, Mumcu E, Arat S. The comparison of marginal bone loss around mandibular overdenture-supporting implants with two different attachment types in a loading period of 36 months. *Gerodontology.* 2011;28(1):49-57. DOI: 10.1111/j.1741-2358.2009.00334.x.

[73] Di Francesco F, De Marco G, Sommella A, Lanza A. Splinting vs Not Splinting Four Implants Supporting a Maxillary Overdenture: A Systematic Review. *Int J Prosthodont.* 2019;32(6):509-18. DOI: 10.11607/ijp.6333.

[79] Sadowsky SJ, Caputo AA. Effect of anchorage systems and extension base contact on load transfer with mandibular implant-retained overdentures. *J Prosthet Dent.* 2000;84(3):327-34.

[74] de Almeida EO, Rocha EP, Freitas AC Jr, Freitas MM Jr. Finite element stress analysis of edentulous mandibles with different bone types supporting multiple-implant superstructures. *Int J Oral Maxillofac Implants.* 2010;25(6):1108-14.

[80] Ebadian B, Mosharraf R, Khodaeian N. Effect of cantilever length on stress distribution around implants in mandibular overdentures supported by two and three implants. *Eur J Dent.* 2016;10(3):333-40. DOI: 10.4103/1305-7456.184152.

[75] de Almeida EO, Rocha EP, Assunção WG, Júnior AC, Anchieta RB. Cortical bone stress distribution in mandibles with different configurations restored with prefabricated bar-prosthesis protocol: a three-dimensional finite-element analysis. *J Prosthodont.* 2011;20(1):29-34. DOI: 10.1111/j.1532-849X.2010.00656.x.

[81] Joshi S, Kumar S, Jain S, Aggarwal R, Choudhary S, Reddy NK. 3D Finite Element Analysis to Assess the Stress Distribution Pattern in Mandibular Implant-supported Overdenture with Different Bar Heights. *J Contemp Dent Pract.* 2019;20(7):794-800.

[76] Semper W, Heberer S, Nelson K. Retrospective analysis of bar-retained dentures with cantilever extension: marginal bone level changes around dental implants over time. *Int J Oral Maxillofac Implants.* 2010; 25(2): 385-93.

[82] Ionescu C, Gălbinașu BM, Manolea H, Pătrașcu I. Implant overdenture and Locator system in edentulous patient with severely resorbed mandible - a case report. *Rom J Morphol Embryol.* 2014;55 Suppl 2:693-6.

[77] Elsyad MA, Al-Mahdy YF, Salloum MG, Elsayh EA. The effect of cantilevered bar length on strain around two implants supporting a mandibular overdenture. *Int J Oral Maxillofac*

[83] Assaf A, Daas M, Boittin A, Eid N, Postaire M. Prosthetic maintenance of different mandibular implant overdentures: A systematic review. *J Prosthet Dent.* 2017;118(2):144-52.e5. DOI: 10.1016/j.prosdent.2016.10.037.

[84] Osman RB, Payne AG, Ma S. Prosthodontic maintenance of maxillary implant overdentures: a systematic

literature review. *Int J Prosthodont.* 2012;25(4):381-91.

[85] Osman RB, Ma S. Prosthodontic maintenance of overdentures on zirconia implants: 1-year results of a randomized controlled trial. *Int J Prosthodont.* 2014;27(5):461-8. DOI: 10.11607/ijp.3626.

[86] Krennmair G, Krainhöfner M, Piehslinger E. The influence of bar design (round versus milled bar) on prosthodontic maintenance of mandibular overdentures supported by 4 implants: a 5-year prospective study. *Int J Prosthodont.* 2008;21(6):514-20.

[87] Cakarar 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.* 2011;16(7):e953-9. DOI: 10.4317/medoral.17312.

[88] ELsyad MA, Errabti HM, Mustafa AZ. Mandibular Denture Base Deformation with Locator and Ball Attachments of Implant-Retained Overdentures. *J Prosthodont.* 2016;25(8):656-64. DOI: 10.1111/jopr.12356.

[89] Payne AG, Solomons YF. Mandibular implant-supported overdentures: a prospective evaluation of the burden of prosthodontic maintenance with 3 different attachment systems. *Int J Prosthodont.* 2000;13(3):246-53.

[90] Watson RM, Jemt T, Chai J, Harnett J, Heath MR, Hutton JE, Johns RB, Lithner B, McKenna S, McNamara DC, Naert I, Taylor R. Prosthodontic treatment, patient response, and the need for maintenance of complete implant-supported overdentures: an appraisal of 5 years of prospective study. *Int J Prosthodont.* 1997;10(4):345-54.

[91] Park JH, Shin SW, Lee JY. Bar versus ball attachments for maxillary four-implant retained overdentures: A randomized controlled trial. *Clin Oral Implants Res.* 2019;30(11):1076-84. DOI: 10.1111/clr.13521.

[92] Naert I, Gizani S, van Steenberghe D. Rigidly splinted implants in the resorbed maxilla to retain a hinging overdenture: a series of clinical reports for up to 4 years. *J Prosthet Dent.* 1998;79(2):156-64. DOI: 10.1016/s0022-3913(98)70210-0.