

Prosthetic considerations

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ABSTRACT

Implants have changed prosthodontics more than any other innovation in dentistry. Replacement of lost teeth by a fixed or removable prosthesis is considered to be a *restitutio ad similem*, while implants may provide a feeling of *restitutio ad integrum*. Implant prosthodontics means restoring function, aesthetics, and providing technology; biology and technology are combined. Placement of implants is a reconstructive, preprosthetic surgical intervention and is therefore different from most goals in oral surgery that consist of tooth extraction, treating infection and removing pathology from soft or hard tissues. Thus, implants are part of the final prosthetic treatment which encompasses functional, aesthetic and social rehabilitation. The patient's needs and functional status determine the goal of prosthetic treatment. Treatment outcomes in implant prosthodontics are survival of implants and prostheses, impact on physiological and psychological status, oral health-related impact on quality of life, and initial and maintenance costs. A variety of prosthetic solutions are available to restore the partially and completely edentulous jaw and more recently specific methods have been developed such as computer guided planning and CAD-CAM technologies. These should allow more uniform quality and passive fit of prostheses, and simultaneously enables processing of biologically well-accepted materials.

Key words: Prosthesis design, fixed, removable, materials, CAD-CAM.

Abbreviations and acronyms: FPP = fixed partial prostheses; EBM = evidence-based medicine; OHIP = oral health impact profile; RCT = randomized controlled trials.

INTRODUCTION

The seminal work of Brånemark and co-workers had one primary goal: to restore the edentulous jaw by means of fixed prostheses supported by “titanium roots”. This should approach what is meant by *restitutio ad integrum*. This treatment goal could be achieved more often in the mandible than maxilla for several reasons. Within this treatment concept the overdenture prosthesis was not considered a viable solution, and was regarded as inferior to fixed prostheses.

The systematic and scientific approach to developing the concept of osseointegration and implant dentistry is documented in the first comprehensive overview in 1985 by Brånemark and co-workers¹ which represented the gold standard at that time for this field of dentistry. The book chapters, particularly describing the treatment of the edentulous maxilla, reveal an insufficient understanding of proper implant placement related to the prostheses, as well as inadequate laboratory technology, and a lack of sophisticated planning tools. Further, it must be considered that adjunctive tech-

niques to improve and optimize implant position (e.g., local bone regeneration, local grafts, sinus floor elevation and complete grafts) had not been considered.

The technical aspects of retention (screw retention) and fabrication of prostheses in the early period of implant dentistry posed many problems. Passive fit was difficult to achieve, particularly with large frameworks of precious or non-precious alloys. The selection of secondary components (abutments, analogs, screws, impression copings and healing caps) was limited and was subjected to frequent complications. Later implant companies introduced new implant designs and changed the connection between implant and superstructure, offering a variety of components. This facilitated fabrication of prostheses and fulfilled the demands of prosthetic designs. It also led to an abundance of components and was confusing.

The clinical experience over time from practising implant dentistry, particularly the prosthetic component, resulted in an improved understanding of prosthetically-driven implant planning and placement. A more recent breakthrough in implant-prosthetic technology has been CAD-CAM technology.

While the original concept of osseointegration proposed by Brånemark focused on the treatment of the edentulous patient by fixed prostheses, others suggested restoration of the partially edentulous situation (particularly with Kennedy Class I and II) with fixed prostheses, avoiding removable partial dentures. Further, the overdenture solution was proposed for the edentulous mandible with four implants and a connecting bar.

Biological research laid the scientific basis for the concept of osseointegration in the late 1960s and 1970s. The prosthetic concepts and technology developments occurred in the 1980s. Since then a rapid and broad evolution in implant dentistry has occurred with an exponential increase in publications.

The edentulous jaw

Fixed prostheses

Differences are found regarding prosthetic design and number of implants. However, the evidence from the literature on prosthetic aspects is minimal, mostly survival rates of implants are reported. As mentioned in the introduction, rehabilitation with a fixed prosthesis was a priority goal in implant prosthodontics and the first long-term results were presented in the Toronto study by Zarb and Schmitt.² In these early publications, restorations for the edentulous mandible predominated compared with the maxilla with limited reports. The prostheses were designed around a metal-framework from precious-alloy with acrylic veneering. The so-called “wrap-around” technique with prefabricated acrylic denture teeth and denture base material to compensate for lost hard and soft tissues was also applied. These prostheses were supported by a minimum of 4 and mostly 5 to 6 implants, and were screw retained, with a hybrid design (where the prosthesis material was not in contact with the alveolar mucosa). The implants were placed in the interforaminal/anterior regions thus avoiding the mental nerve or sinus, but cantilevers and shortened dental arches became necessary. Loading patterns of these types of prostheses were investigated and demonstrated maximum loading forces on the distal implants adjacent to the cantilevers. The reason for the limited number of maxillary cases was due to the advanced atrophy and anatomical conditions that often did not allow placement of implants posteriorly. Thus, most prostheses at that time exhibited long cantilevers with the risk of cantilever fracture.

Long-term results and comparative studies with different designs of fixed prostheses (wrap-around technique or ceramometal with a fixed prosthesis design) in the edentulous jaw were not available. A recent study reported on the “clustering effect” with

multiple implant failures in the edentulous maxilla.³ In studies on implant survival or success the design of the prosthesis is often not clear and the authors focus more on bone level changes than on prosthetic aspects. The fixed prosthesis design is expensive, may pose aesthetic problems such as long teeth and absence of a natural soft tissue contour, particularly in the maxilla, and requires absolute congruence of implant and prosthetic tooth position. Full-arch fixed prostheses are technically complex, passive fit may not be achievable, and screw retention requires an optimal vertical implant axis. Angled abutments may overcome the implant alignment problems but complicate rather than facilitate the technical process. Due to the maxillary resorption pattern, insufficient lip support may result with fixed prostheses, and fixed prosthesis with the wrap-around technique more easily overcomes anatomical and aesthetic problems. Case series and single case reports demonstrate that the number of implants to support the prostheses varies widely from 5 to 10 or even 12 in the edentulous jaw.

Today the type of wrap-around prostheses has a highly improved design. The fabrication of large frameworks is optimized by CAD-CAM technologies, which mostly use titanium, and more recently also zirconia. Recent clinical case series deal mostly with full ceramic material and high strength ceramics for single tooth replacement and short span fixed partial prostheses but not on titanium. Both materials have the advantage of light-weight compared with gold alloys. Computer technology facilitates framework production of uniform quality and precision. The CAD-CAM technology maintains the quality of the material since it is processed from homogenous blocks without heat. From a technical view, it appears desirable that such frameworks are connected directly to the implant shoulder without abutments, involving fewer components in the superstructure. Passive fit can be improved significantly and the gap between superstructure and implant shoulder is minimized. It is not clear whether passive fit is important for osseointegration or remodeling, i.e., the maintenance of the implants in the bone. But reduction of stress and tensile shear forces in the superstructure provides protection for the superstructure itself, with less screw retightening, fewer framework fractures and less chipping of veneering material.

Computer technology and CAM-processing allow for optimized, prosthetically driven implant planning, placement and even fabrication of the prostheses before implant placement. The 3-D computer technology combined with guided (flapless) surgery offers advantages when implants are planned for the edentulous maxilla.⁴

Figure series 1 show typical designs of fixed prostheses in the edentulous jaw and clinical considerations, represented by graphic illustrations.

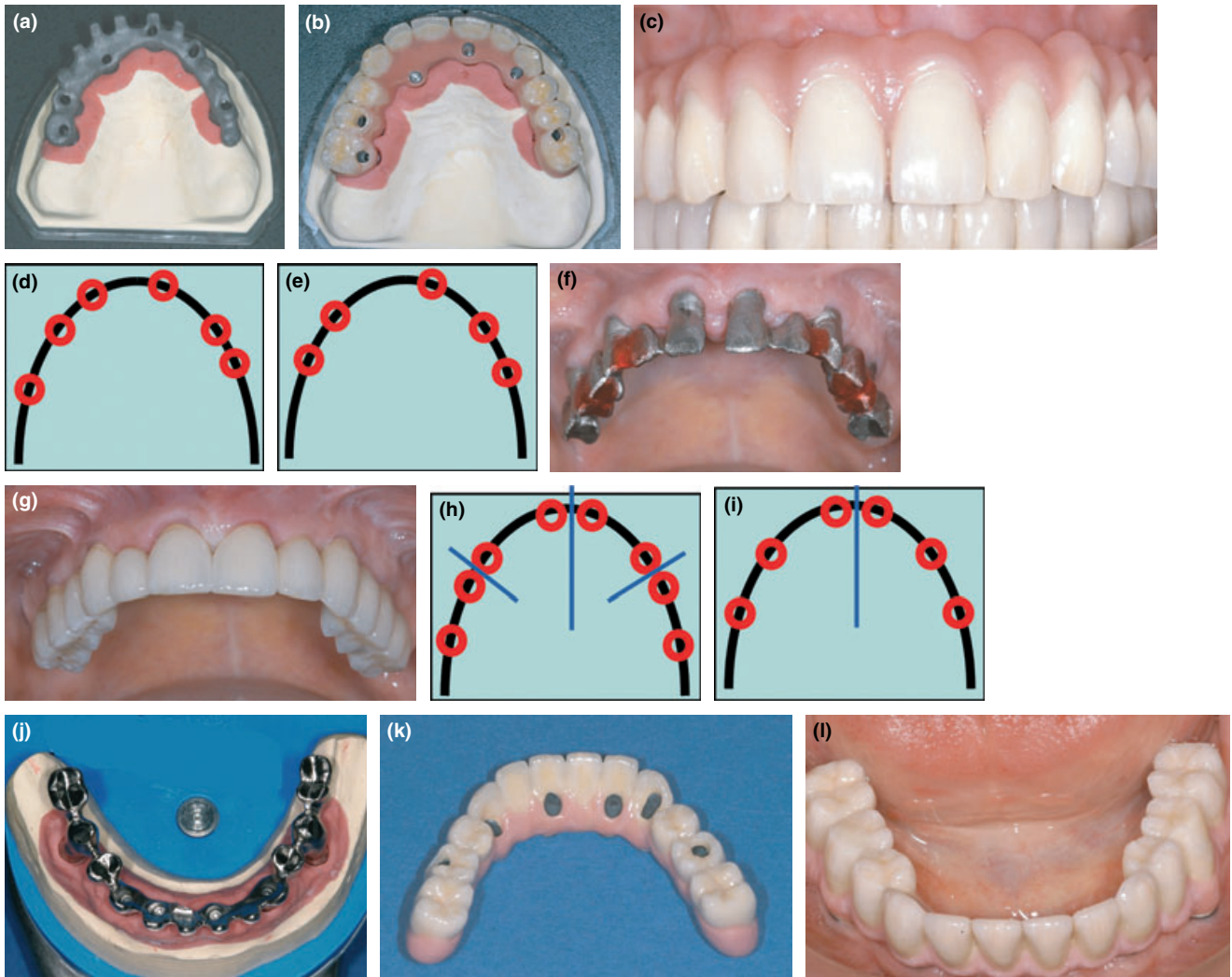


Figure series 1. Fixed prosthesis, edentulous jaw. (a) Fixed cantilever prosthesis with CAM titanium framework on 6 implants. (b) Wrap-around technique, extremely light weight of prosthesis (18 g). (c) Aesthetic appearance. (d) and (e) Graphic illustrations: possible distribution of 5–6 implants for fixed cantilever prosthesis (CAD-CAM technology and titanium framework with wrap-around technique). (f) Fixed metal framework for ceramometal bridgework. (g) Full-arch bridgework, with 6–8 implants, clinical view, increased weight (86 g). (h) and (i) Graphic illustrations: Distribution of 6–8 implants and possible segmentation of framework. (j) CAD-CAM titanium framework. (k) Mandibular fixed prosthesis supported by 6 implants. (l) Titanium framework with ceramic veneering.

Overdentures

A large body of literature on overdentures is available. Preferred topics are the number of implants and the retention mechanism with regard to retention and complications.

The overdenture has become a preferred treatment modality, particularly for elderly and maladaptive patients exhibiting problems with wearing mandibular dentures. Four interforaminal implants with a connecting bar for denture support were often suggested to obtain cross-arch stabilization and to better maintain osseointegration. So far there is no study that confirmed the superiority of 4 compared with 2 implants for mandibular overdentures with regard to implant survival. Two mandibular implants was proposed in the late 1980s⁵ and 10 years later the majority of studies

on mandibular overdentures were based on 2 and occasionally 3 interforaminal implants. It was even proposed as the standard of care for the edentulous mandible⁶ although this statement is disputed controversially.

A major topic in overdenture rehabilitation, also disputed and controversial, is the use of bars or single anchors and the retention mechanism, i.e., resilient or rigid. With two interforaminal implants, the overdenture has combined tissue and implant support. It is believed that single ball anchors or rotational bars provide the best resilient anchorage in this situation. There is, however, a lack of studies to prove a negative effect of rigid bar support. A long-term study observed no differences in crestal bone level changes with resilient bars or single ball anchors.⁷ Another study observed more technical problems with round clip bars

(resilient support) compared with single ball anchors⁸ but this study compared two resilient retention systems. In fact the small clips are prone to mechanical complications. Although patients are highly satisfied, frequent maintenance with ball anchors has been reported.⁹ Another long-term study with up to 15-year data reported that both resilient retention (clip bar, single ball anchors) required more maintenance and were more often changed than rigid bars.¹⁰ There is also some concern that mandibular overdentures may encourage posterior jaw resorption. In contrast, vertical bone apposition in the posterior jaw was reported in some clinical observational studies with fixed cantilever prostheses. As a result it was recommended to provide younger edentulous patients with fixed mandibular prostheses.

Figure series 2 shows various designs of mandibular overdenture retention devices in the edentulous jaw and clinical considerations, represented by graphic illustrations.

The situation with maxillary overdentures is different. Early studies reported a high failure rate (biological failures), which is explained by the specific indication given for this treatment modality, i.e., compromised situations with osteoporotic bone and advanced jaw atrophy. This allowed for placement of only a limited number of small sized implants. Thus, overdenture

treatment resulted in a selection of risk patients who often had experienced failures with fixed prostheses and therefore received overdentures supported by the remaining implants.¹¹ Increased success was achieved with careful patient selection and technical protocols of overdenture fabrication¹² in various studies. For maxillary overdentures the support by only 2 implants is not suggested as the definite treatment but as a temporary solution with full palatal coverage of the prosthesis. A connecting bar is not feasible with 2 implants and sufficient stability is mostly not provided. In cases of multiple implants – 4 to 5 and connecting bar – a horseshoe design is suggested with a metal-framework to reinforce the denture base. Due to the specific anatomical features a divergence in the implant axis is often observed. This hinders the vertical insertion path for the prosthesis if connected to multiple single ball anchors or locators, although providers ensure proper fit with up to 40° of divergence. A well-positioned bar, connected to 4 or 5 implants, which follows the anterior arch curvature may solve the problem. This type of overdenture has appropriate implant support, imitating a rigid fixed prosthesis with regard to biomechanical aspects. Soldered bars from gold alloys are vulnerable to fracture. CAM technology allows the fabrication of titanium bars which reduces the fracture problem, even with cantilevers.

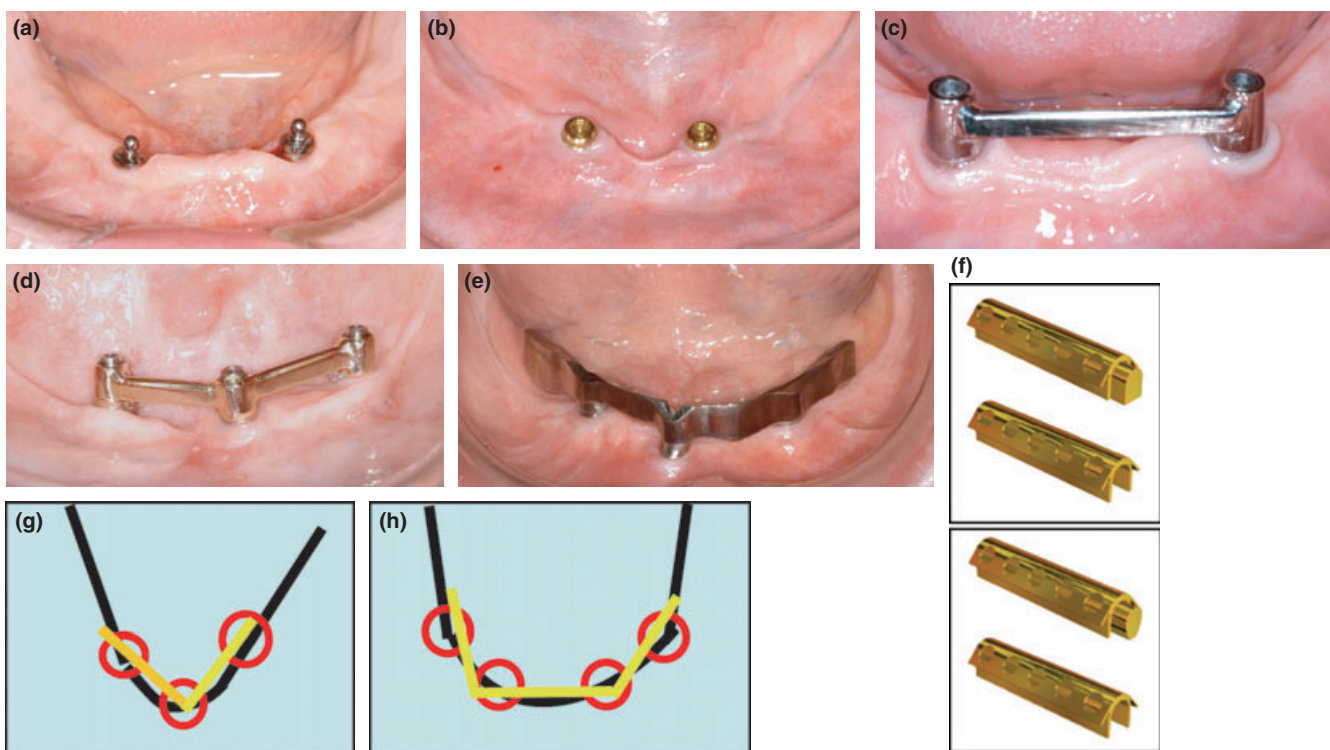


Figure series 2. Overdentures mandible. (a) and (b): Single anchors: ball anchors, locators. (c) Soldered bar, gold alloy on 2 implants. (d) On 3 implants, with more pronounced anterior curvature. (e) Alternative: milled bar from titanium (CAD-CAM). (f) Dolder bars: egg shaped, u-shaped. (g) and (h) Graphic illustrations: with a V-shaped jaw or large anterior curvature, 3 or 4 implants are suggested. The single bar segments should have a length of ≥ 15 mm.

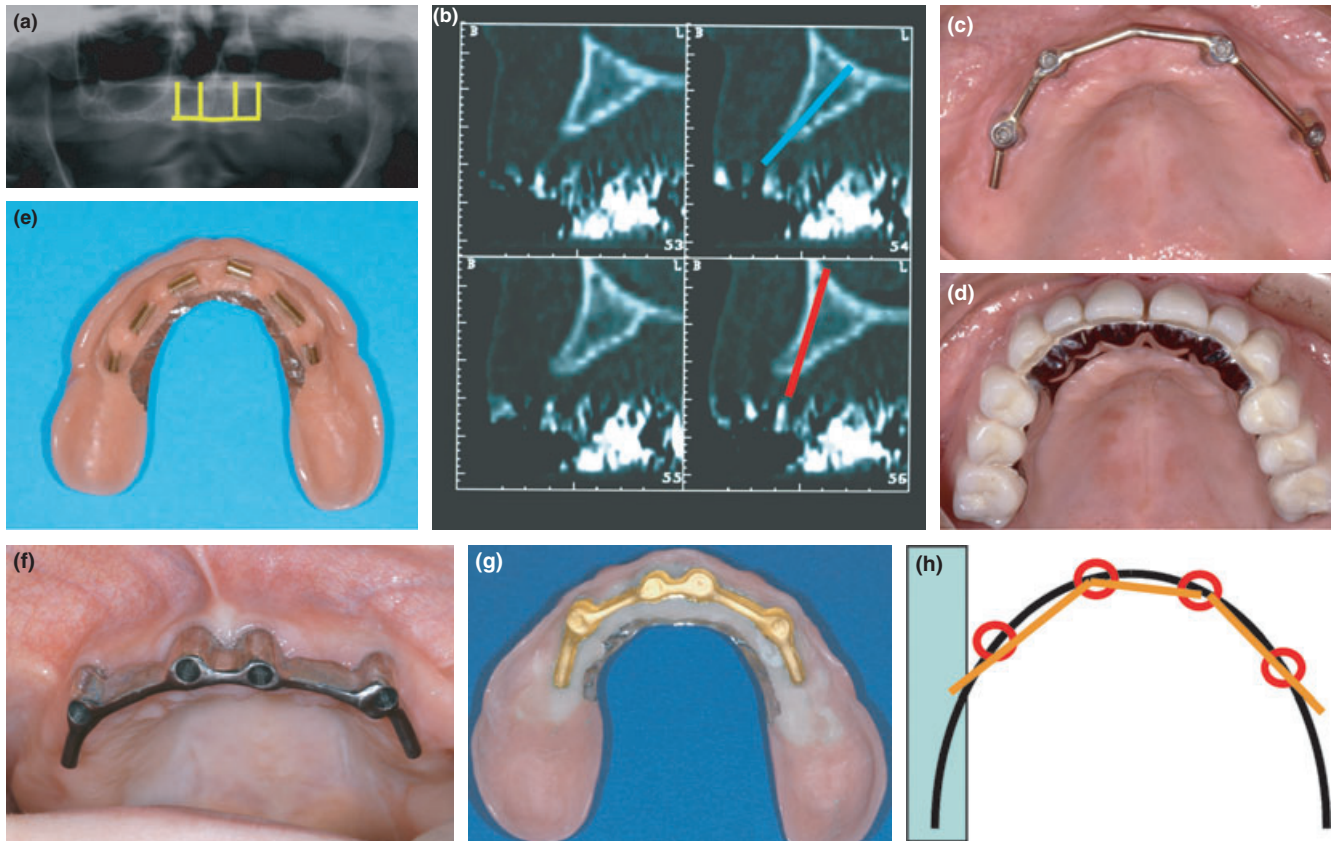


Figure series 3. Overdentures maxilla. (a) Orthopantomogram: 4 implants with bar planned in the anterior region between first premolars or canines, no conflict with sinus. (b) CT slice: buccally oriented implant axis (blue) – compatible with bar, a more vertical axis (red) must be planned for fixed prosthesis with screw retention. (c) Soldered bar, gold alloy with 4 implants, large distance between both anterior implants, bar with angulation. (d) and (e): Horseshoe OD with reinforced with metal framework. (f): Milled bar from titanium (CAD-CAM). (g): Galvanoforming female retainer. (h) Graphic illustration: Distribution of implants, 2 anterior implants should preferably be in rather close position, otherwise bar will not follow anterior curvature or must be slightly bended (c).

Figure series 3 shows various designs of maxillary overdenture retention devices in the edentulous jaw and clinical considerations, represented by radiographic and graphic illustrations.

There remains the question of whether fixed or removable prostheses should be recommended for patients with edentulous jaws. For mandibular prostheses in many cases both options are a viable solution with interforaminal implants; while in the maxilla, the decision is determined by anatomical situation, considerations of surgical procedures that may be necessary for implant placement, and costs. Studies have reported that the patients' choice is rather dependent on individual preference, e.g., ease of oral hygiene procedures. Speech analysis in cross-over testing revealed better results with overdentures for some speech sounds.¹³ The design of fixed prostheses, however, is not clear for ceramometal fixed partial prosthesis design or cantilever prosthesis with acrylic teeth and denture base material. Otherwise soft tissue problems such as inflammation and hyperplasia are often observed with bar-stabilized overdentures.

The recommendations on the number of implants to be used for fixed and removable prostheses vary and are dependent on individual preferences, mechanical considerations and technical aspects. Most studies on prosthesis design and retention do not sufficiently consider factors that influence function of prosthesis, including interarch relationship, degree of jaw atrophy, orientation of implant, dentition/prosthesis in the opposing jaw, and type of occluding materials, occlusion and loading. Table 1 exhibits a summary on prosthesis and implants in the edentulous jaw.

Fixed partial prostheses (FFP or short-span bridges) including single crowns

Compared with removable prosthesis, less information about design and technical aspects is available. The most frequent question was raised on the preference for screw retention or cementation.

With single crowns and FPP, three considerations are relevant: (1) removable partial dentures, which are not always well accepted by the patients, are avoided for Kennedy Class I and II situations and eventually for

Table 1. Summary – prosthetic aspects

Indication	Outcomes, recommendations, problems
Edentulous maxilla	
2 implants	Overdenture: temporary, full palatal coverage
4–5 implants	Overdenture: palatal free, bar preferred to single anchors, metal-framework, facial support provided
5–7 implants	Fixed cantilever with wrap-around titanium CAD-framework, screw retained, facial support provided
8–10 implants and good bone space available:	FPP ceramometal: segmented (screw retained), symmetrical distribution suggested
	≥15 mm between maxillary crest and mandibular teeth: Overdenture or wrap around suggested
	≤10 mm: fixed prosthesis suggested
Sagittal Class III/need for lip support	Overdenture and fixed cantilever prostheses suggested
Edentulous mandible	
Interforaminal position	
2–3 implants	Overdenture: bar or single anchors (curvature!)
4 implants	Overdenture: rigid bar preferred to single anchors metal-framework, length of bar segments!!!
4–6 implants	fixed cantilever prosthesis, wrap around titanium CAD-framework, screw retained
Anterior posterior	
≥ 6 implants, good bone	FPP ceramometal: segmented (screw retained), symmetrical distribution suggested
4 implants in position of teeth ^{33,35,43,45}	For shortened dental arch

anterior partially edentulous spaces; (2) there is no need to involve adjacent (healthy) teeth or crowned teeth with intact restorations. In this sense implants contribute to the maintenance of the natural teeth; (3) the problem of tooth supported FPP with posterior cantilevers, which appears to be more prone to failure without a distal abutment tooth is overcome.¹⁴

Today clinicians tend to replace conventional tooth-supported FPP by implant-supported restorations. This is favoured by adjunctive surgical techniques which enable the clinician to place implants in zones where the anatomy and remaining bone would not have allowed it previously. The question is also disputed whether endodontically treated teeth and broken teeth should be maintained and restored with posts and cores, or be replaced by implants, which may have a better prognosis. Altogether a paradigm shift with regard to maintenance or extraction of teeth has occurred.

In the posterior zone aesthetic aspects are less critical than in the anterior region. **As a result of posterior jaw atrophy, large and long prosthetic teeth cannot be avoided, since they also replace the soft and hard tissue lost after tooth extraction.**

Long-term results show good prognosis for implants supporting FPP,¹⁵ although cross-arch stabilization is not provided. A high survival rate for the restorations was found with no statistically significant difference between anterior and posterior sites. High static and dynamic loads in centric and eccentric contact situation are expected for FPP in the posterior zone. Accordingly, some clinicians recommend to use 3 to 4 implants preferably in staggered positions to replace ≥ 3 missing teeth, while other clinicians prefer a design with pontics and/or cantilevers and two supporting implants, similar to conventional tooth-supported FPP. Comparative studies and randomized controlled trials (RCT) are not available to demonstrate the superiority of multiple implants.

It can be argued that in case of an implant failure the superstructure will not be lost with multiple implants.

A high occurrence of service and maintenance was recently observed with cemented and screw-retained FPP and single crowns, with a tendency to more complications in the molar region or with longer frameworks.¹⁶ The study material comprised one implant system and it might be considered that this complication rate is specific for this but not valid in general.

Although combined tooth-implant support is positively documented in case series and comparative trials, it should be avoided, since technical problems appear to be frequent.¹⁴

Dentists now have the choice to select among different secondary components or individually fabricated abutments for fixation of a FPP, in combination with screw retention or cementation. But, the problem of passive fit – to a lesser extent – also exists when fabricating frameworks for FPP by means of conventional techniques from gold alloys. It was observed in laboratory studies that with cementation, passive fit is more easily reached but with a larger gap of the crown margin. Screw retention provides better precision of the crown margin with smaller gaps but more framework tension.¹⁷ The framework without access-holes for occlusal screws – i.e., for cementation – facilitates fabrication and improves the form of the occlusal platform. Prefabricated abutments are also used which may compensate for non-parallel implant placement.

Figure series 4 shows cementation and screw retention for ceramometal FPP in the posterior zone.

Studies on single crowns report a high survival rate. Single crowns for small spaces allow a design of an occlusal scheme that restricts heavy contact in centric occlusion and avoids lateral guidance. Thus single implants are protected by adjacent teeth. Single implant crown replacement between teeth is frequently used in

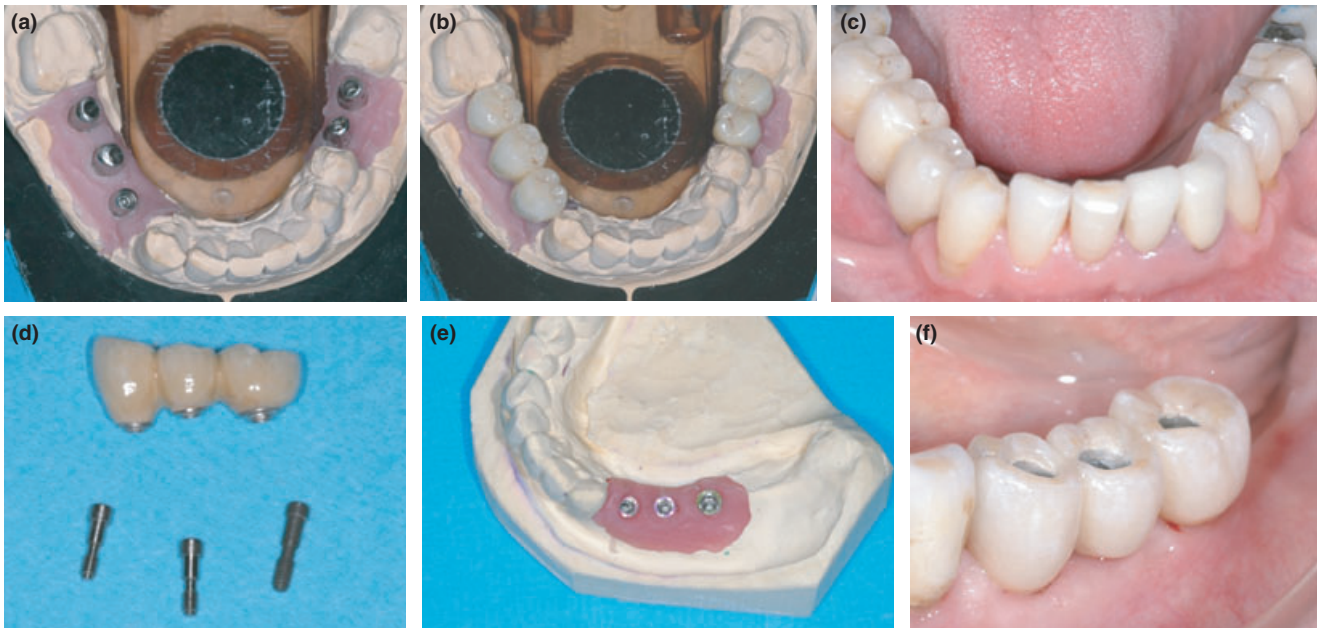


Figure series 4. Fixed partial prosthesis, large gap or distal extension (FPP, ceramometal). (a) 3 and 2 missing teeth are replaced by 3 respectively 2 implants titanium abutments. (b) FPP on 2 and 3 implants each on the cast, no access hole for occlusal screw. (c) Cemented, clinical view. (d) 3 connected, screw retained crowns. (e) Distal free-end situation left mandible. (f) Screw retention, occlusal access hole visible, clinical view.

the aesthetic zone, i.e., maxillary anterior region. In this region, natural aesthetics with natural papilla formation is highly demanding and needs to respect biological principles. It is dependent on implant position and particularly on crestal bone level of adjacent teeth. This topic is significant also with regard to abutment selection and superstructure material.

Although the majority of clinicians are reluctant, a trend to use all ceramic (high strength) material is observed in combination with zirconia implant abutments. Screw-retained frameworks from zirconia for single crowns and fixed prostheses of multiple crowns have been enthusiastically introduced in clinical practice and preliminary reports are in progress. CAD-CAM fabrication provides high precision and fit of frameworks. The strength of zirconia exceeds that of other all-ceramic systems, but laboratory investigations cannot predict its long-term behaviour in the oral cavity. Etching and adhesive cementation which increases the strength of various types of glass ceramics is not possible with zirconia. Some difficulty also exists to obtain natural aesthetics, i.e., natural colour and lustre, since zirconia is extremely white and not translucent. Nevertheless, good biological characteristics and high precision of CAD-CAM fabrication enhances aesthetics and health of the soft tissues and absence of a greyish shine of the gingival border (as may be seen on ceramometal crowns).

Figure series 5 shows zirconia abutments, crowns and FPP in the aesthetic zone, with cementation and screw retention. Table 2 exhibits a summary on prosthesis and implants in the partially edentulous jaw.

Immediate loading

Implant survival is the most important outcome, with no quality data available on preferred prosthetic protocols. The majority of studies on immediate loading with high level evidence are for mandibular overdentures.

During the pioneer periods (late 1970s to early 1980s) of dental implantology, immediate loading was practised on mandibular interforaminal implants. Scientific evidence was not available at that time. The results of carefully designed research protocols and animal studies suggest that an unloaded healing period is recommended with longer healing times specific for maxilla and mandible. With the recent introduction of new surfaces, i.e., only moderately rough instead of machined or rough and enriched with molecules (e.g., phosphor, fluorides, magnesium, liquid NaCl), shorter healing periods have been proposed. Some confusion in terminology is observed in the literature. Correctly, “immediate loading” means loading by the connection of the prostheses within 24 to 48 hours; “early loading” means loading within three days and up to ≤ 6 weeks, which corresponds with the recommended healing time when implants with new surfaces are placed. The best evidence for immediate loading with controlled patient groups is available for the edentulous mandible with interforaminal implants.¹⁸ This was also the unanimous outcome of several consensus conferences held over the last three years.

Successful treatment was demonstrated with overdentures, either with 2 single ball attachments, or with

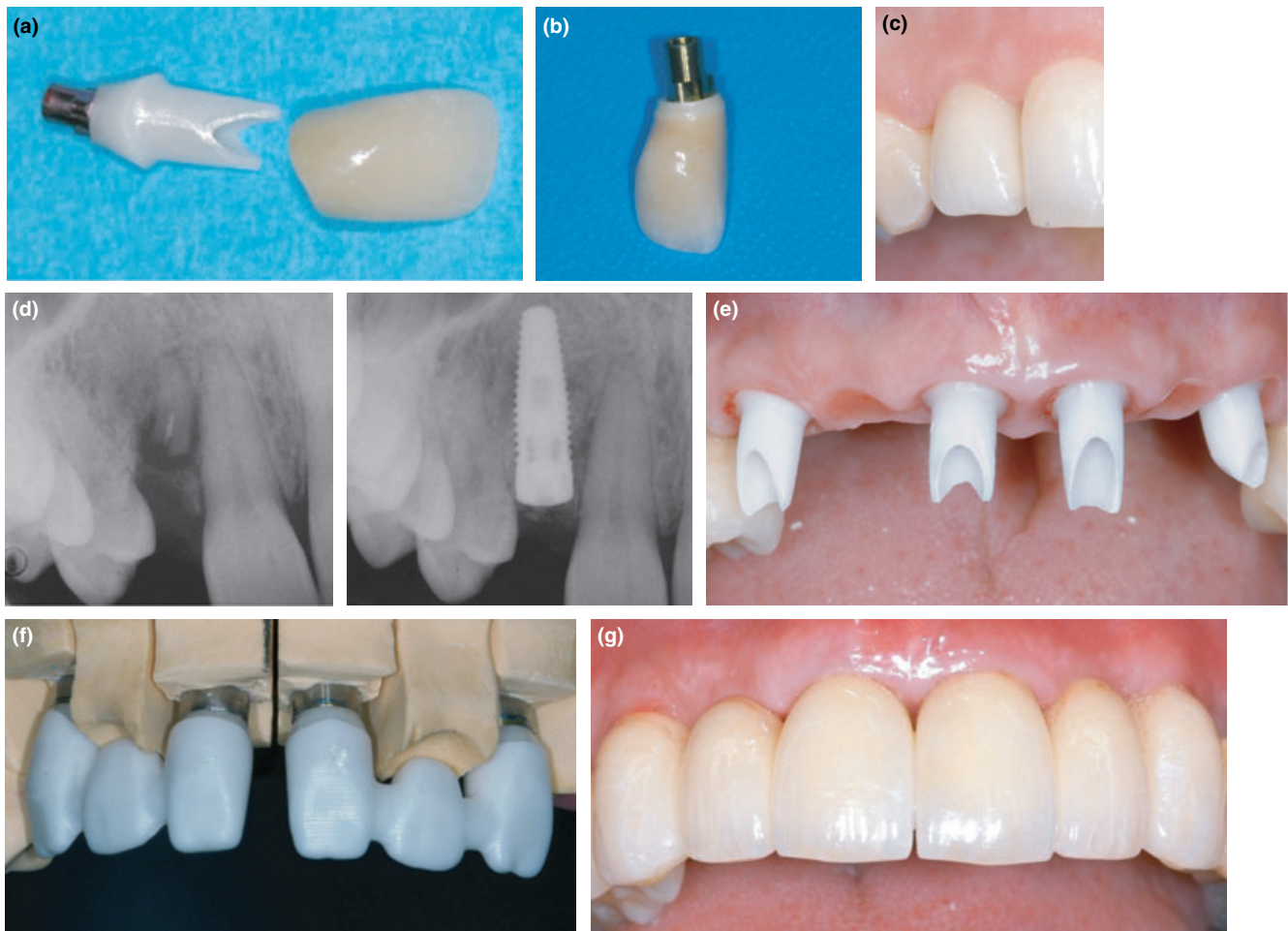


Figure series 5. Zirconia, CAD-CAM fabrication. (a) Zirconia abutment with ceramic crown for cementation. (b) Zirconia crown, screw retention in the aesthetic zone. (c) Zirconia crown on implant, replacing missing lateral incisor, clinical view with good aesthetical result. (d) Radiographic illustration before and after, bone height favourable at adjacent neighbouring teeth. (e) Zirconia abutments in anterior maxilla for cementation of short span FPP from zirconia. (f) Zirconia framework, on cast. (g) 3-unit cemented zirconia bridgework, 2 segments, clinical view.

Table 2. Summary – prosthetic aspects

Indication	Outcomes, recommendations, problems
Fixed partial prosthesis 3–4 missing posterior teeth	3–4 implants >2 impl. Ceramometal(still standard) or CAD-CAM zirconia
Screw retained Cemented-on abutments Service and maintenance	small gap, strain in framework larger gap, better passive fit screw tightening Implant/tooth > implant/implant support
Aesthetic zone	Cementation < screw retention Individual abutment (zirconia possible) orientation of axis is important Correction emergence profile Cementation and screw retained: equal results

> more frequent.
< less frequent.

bars or with fixed prostheses. A recent concept of distally inclining the posterior implants provides a larger supporting area for a fixed cantilever prostheses without the need to locate implants to the posterior

jaw.¹⁹ Force patterns on these inclined posterior implants have not been analysed and measured. Studies on immediate loading have mostly reported on biological outcomes under different prosthetic designs and to a lesser extent on prosthetic aspects *per se*. A randomized controlled trial (RCT) on immediate loading in the mandible with 2-implant overdentures found greater need for maintenance and service compared with standard treatment.²⁰ This could be attributed to the prosthetic protocol that was followed in the study and would need modification, but overall the treatment outcome was positive.

Little information is available about immediate loading in the edentulous maxilla. Some case reports have demonstrated methods and techniques, either with bar overdentures or fixed prostheses. More often it is suggested in combination with guided surgery and fabrication of the prostheses before implant installation.⁴

The immediate loading protocol for the edentulous jaw requires careful planning and a preparatory phase in close cooperation with a laboratory technician.

Table 3. Patients' response and evidence in implant prosthodontics

Parameter	Outcome
Survival of implants	
Longevity	mandibular > maxillary implants single crowns high
immediate implants	interforaminal safe (good evidence)
Physiological impact	
mastication, nutrition	mandibular overdenture > complete denture
biting forces	mandibular overdenture > complete denture
bone remodeling	not clear
phonation	edentulous maxilla overdenture > fixed
Psychological impact	
satisfaction, well being, quality of life	mandibular overdenture > complete denture. Long bar, single attachments: similar max. Overdenture equal to fixed prosthesis
handling, hygiene	Individual preferences. Overdenture > fixed in elderly patients
Aesthetics	maxilla: overdenture better lip support
Cost	
direct	Implants > natural teeth Overdenture > complete denture Overdenture < fixed prosthesis
indirect (service, maintenance)	Fixed < overdenture, not clear
investment of time	ball anchors > bars > rigid bars overdenture < fixed, not clear

> better or more frequent.

< less frequent.

OD: overdenture.

CD: complete denture.

Simple overdentures, if well prepared, may be converted directly and easily into the final prostheses. But in general, provisional immediate prostheses are constructed from acrylic resin and require replacement later with the final superstructure with a metallic framework. Thus, immediate loading enhances comfort and rapid rehabilitation (functional, social, aesthetic). It may also contribute to the protection of the implants and surgical site during the healing phase with a properly designed prosthesis; however, it increases costs.

A semantic distinction should be made between immediate loading and immediate restoration. Implants are required to withstand full occlusal loading from the beginning if full-arch prostheses or fixed partial prostheses in the posterior zone are immediately connected to implants. Provisional restorations from acrylic resin may function as "shock absorbers". Single crown restorations in the anterior region can be protected from heavy occlusal contacts. Patients are advised not to bite hard foods with such an immediately replaced tooth.

Currently, immediate implants placed into extraction sockets with immediate restorations for single anterior tooth replacement is also disputed in the literature. The problems of infection, buccal bone resorption, soft tissue recession and compromised aesthetics have been

raised, suggesting delayed placement of crowns as a standard procedure. This contrasts with the idea that immediate implants and immediate restorations will maintain bone structure and soft tissue and therefore reduce collapse and resorption. Some case reports and case series have shown that both methods can be successful.

Patients' response: impact on oral health-related quality of life and maintenance

Recent studies exhibit high interest in the physiological and psychological benefit of implant prostheses. According to the definition by Sacket *et al.*²¹, evidence-based medicine (EBM) is: (i) best research evidence (basic research but more important clinical studies); (ii) clinical expertise; and (iii) patients' values.

Treatment outcome classification in implantology,²² which in some way translates into quality of life are: (1) longevity/survival of implants and prostheses; (2) physiological impact: chewing, bite forces, bone modeling/remodeling; (3) psychological impact: satisfaction and well-being with prostheses, self-esteem and interpersonal relation, aesthetics; (4) economic impact: costs (direct/indirect), maintenance service.

Quality of life measurements indirectly integrate these criteria because they are reflected in the patients' subjective experience and judgement of treatment. The negative impact of complete mandibular dentures on quality of life and positive outcome of implant-overdentures is well documented. Obviously the RCT study design including crossover testing can more easily be applied in mandibular denture/overdenture investigations than with other implant prosthetic treatments. Satisfaction with chewing, with stability of the denture, including different anchorage devices for overdenture retention, ease of handling and hygiene procedures, aesthetics and social well-being have been examined. Patients expressed their opinion using visual analogue (VAS) scales and questionnaires such as oral health impact profile (OHIP – short version). High satisfaction was expressed with 2 immediately loaded implants and overdentures.^{23,24}

The effect of 2-implant mandibular overdentures on nutrition was positive with no need for more implants or fixed prostheses.²⁵ The largest number of patient-centred studies on implant prostheses and related quality of life aspects has been with mandibular overdentures as confirmed by a recent systematic review.²⁶ Similar clinical investigations with other types of prostheses and implants are mostly lacking. One exception is a crossover study comparing fixed prostheses and maxillary overdentures. The results suggest that some functions were rated higher by patients with overdentures supported by multiple implants.

RCTs provide the highest level of evidence and should have greatest impact on evidence-based dentistry and decision making in treatment planning. A minor drawback of these studies is the small number of patients and short observation periods of only two months and up to one year. While the quality of the study design is not disputed, the quality of the treatment that was delivered for patients was not critically appraised. For clinicians and daily practice, retrospective analyses with large patient numbers and from various centres would also be valuable.

Complications, failures and costs (initial and maintenance requirements) are interesting aspects of implant prosthodontics in daily practice, but are difficult to control and compare. Data from clinical investigations depend on the type of prosthetic reconstruction, the selection of the implant system with its specific components, technician's skills, materials used and patients' opinions and information. The healthcare systems and economics that are different in different countries influence the selection of type of prosthesis and number of implants. Therefore, time measurements for treatment and net costs of components/materials in relation to the socio-economic conditions provide more reliable comparisons.

Some investigations focused on a comparison of maintenance between fixed and removable prostheses in the edentulous patient; initially, in the first year after treatment more service was required than in following years, irrespective of the type of prosthesis, but with a higher frequency for bar-overdentures.²⁷ Otherwise, a frequent service including tightening of bar screws or female retainers is easily performed and less time consuming than most service that is required for fixed prostheses.

We all acknowledge that oral health and comfort has an impact on quality of life, but there is a lack of specific parameters to be used for decision making in prosthodontic treatment planning with or without implants.

CONCLUSIONS

Although there is a tendency to offer fixed prostheses to our patients, this varies with demographics, such as an increase in the ageing population, with an increase of a reduced dentition, and low socio-economic wealth in many parts of the world. While many patients prefer a fixed prosthesis for the edentulous jaw, this is not confirmed by patient-centred studies. Overdentures may offer many advantages – number of implants, costs, ease of handling and hygiene, although long-term analysis of direct and indirect costs are not yet clear.

Gold alloys are still used in a high percentage (up to 80 per cent) of fixed prostheses; CAD-CAM technologies are becoming more popular in implant prosthodontics with titanium and high-strength ceramics. It results in a more uniform quality and a reduction of time-consuming and invasive patient procedures. In the past, technology and biology were often considered to be contrasts. Today this view is different since new materials exhibit excellent tissue compatibility and modern technologies enhance precision and passive fit of prostheses which may contribute to stable ecological conditions of the oral cavity. In aesthetically-demanding sites, individual cast abutments with an optimum emergence profile made from zirconia is an option.

There is sufficient evidence that immediate loading works well with mandibular interforaminal implants. Primary stability is mostly reached in this bone quality. New surfaces tend to improve and accelerate the osseointegration process and secondary stability. Immediate loading is more and more expanded to different sites in the oral cavity. Still the best way to prefabricate prostheses without significantly increasing costs has not yet been demonstrated. Cross-arch stabilization by bars or fixed prostheses enhance primary stability. These types of prostheses lead to full loading. Single crowns may be protected by neighbouring teeth and heavy loading can be avoided, and may therefore be regarded as an immediate restoration rather than a reconstruction.

The need and extent for maintenance of implant prosthodontics is not clear. There is no good definition of service, maintenance and complications to distinguish between maintenance and complications. Studies have used different parameters and as a result, comparisons are difficult. The distinction is a quantitative one and determined by the parameter "frequency". If a "normal" service becomes excessive it has to be considered a complication or a technical problem. This may also depend on the implant system specifically on the secondary components available for the implant systems.

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