A MULTIMEDIA EDUCATIONAL MODULE FOR THE RESTORATION OF SINGLE-TOOTH IMPLANTS

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Abstract:

Key words: "*Dental Implants, Single-Tooth; Dental Prosthesis, Implant-Supported; Dental Prosthesis Design; Dental Restoration, Temporary; Dental Abutments; Dental Occlusion."*

Aims:

The aim is to review the literature on the restoration of a single-tooth implant, and to develop evidence-based multimedia educational module for undergraduate students to optimize aesthetic, biologic and patient-related outcomes.

Methods:

An electronic and hand-search was conducted using search-terms "*Dental Implants, Single-Tooth; Dental Restoration, Temporary; Dental Impression Materials; Dental Impression Technique; Dental Prosthesis, Implant-Supported; Dental Prosthesis Design; Dental Abutments; Dental Occlusion; Maintenance; Survival;"* and *"Survival Analysis*". Resultant titles were screened, and full text was obtained where relevant. The authors selected the most appropriate articles, giving preference to systematic reviews and long-term, patient-based data.

Results:

Thirty-nine articles were selected and critiqued by the authors.

Conclusions:

There was strong suggestion by several authors that peri-implant soft-tissue aesthetics can be sculpted through provisional restoration contour, however there are no clinical outcome studies to define this. Laboratory studies demonstrate that pick-up type impression copings in conjunction with elastomeric impressions are the most accurate means for transferring implant position to a dental cast. Laboratory and finite-element analysis studies suggest implants with an internal-type connection show improved-stress distribution, however supportive clinical data is lacking. The author of this review favour a screw-retained prosthesis for reasons of predictable retrievability. Clinical and histological studies show that gold, titanium and zirconium abutment materials exhibit excellent biological responses, although there is insufficient clinical data on the clinical service provided by zirconia as an implant-substructure material. The literature does not associate any particular occlusal scheme with superior clinical outcomes. Implant-borne single crowns offer comparable clinical service to tooth-borne fixed dental prostheses, however they are associated with an increased incidence of biological and technical complications.

Introduction:

Historically treatment options to replace a missing single-tooth included a tooth-borne fixed dental prosthesis (FDP), or a removable partial denture (RPD) supported by tooth and/ or tissue. Since the mid-1980s the application of dental implants has broadened to replacement of missing single teeth(1). Although clinical data suggests similar 10 year survival for both FDP on teeth or implants(2), a single-tooth implant does not adversely effect the adjacent dental structures. Medium to long-term data is available on survival and complications of single-tooth implants(1-4), and a recently published meta-analysis of single-tooth implant survival and complications showed 94.5% prosthesis survival after 5 years(3).

Although dental implants have demonstrated excellent clinical survival, longitudinal studies suggest an increased incidence of biological and technical complications when compared with tooth-borne FDPs(2, 4). This is further complicated by what constitutes treatment "success". Recent meta-analyses on implant survival define "success" as clinical service in the absence of biological and technical complications(2, 3). Treatment "success" reported in the literature is judged from the treating clinicians' point of view. Patient satisfaction is based on factors other than absence of complications and includes aesthetics, comfort, and function. As a result the criteria for "success" should be broadened to include objective and subjective outcomes(5). This article examines the relationship in the literature between prosthesis method and biological, technical and patient-related outcomes.

The dental profession is influenced by various sources of information, which may be considered as “evidence–based” (controlled clinical studies with conclusions drawn from outcomes) and “expert opinion”. Whilst there is value in operator experience, it is not quantifiable, and not open to scientific scrutiny.

The application of published clinical data to clinical practice depends on the quality of the evidence. Clinical data may be analysed considering study design and study execution; and design of clinical trials are graded according to scientific validity:

Evidence Rating:	Study design:
1a	Systematic review of randomized control trials (RCT).
1b	Single RCT.
2a	Systematic review of cohort studies.
2b	Cohort study (retrospective) or low level RCT.
2c	Outcomes research.
3a	Systematic review of case-control studies or selected reviews.
3b	Case-control studies.
4	Case-series studies.
5	Expert opinion.

Table 1: From: Journal of Evidence - Based Dental Practice 2002; 2: 6A.

Clinical data may be analysed further into study design (randomisation, blinding, external interest), intervention factors (operator experience and facilities) and patient factors (sample size, cofounding factors). A realistic approach is to identify the strengths and weaknesses of the available clinical data and combine it with clinical experience.

The aim is to review the literature on the prosthetic restoration of a single-tooth implant, and to develop evidence-based conclusions to optimize biological, technical, aesthetic and patient-related outcomes. This requires consideration of the strength of the evidence and identification of areas for future research. The second component to this thesis is the creation of a multimedia educational tool for undergraduate and postgraduate dental students to teach the restoration of single-tooth implants.

Methods:

An electronic search was conducted using the MEDLINE OVID database. Search-terms included "*Dental Implants, Single-Tooth; Dental Restoration, Temporary; Dental Impression Materials; Dental Impression Technique; Dental Prosthesis, Implant-Supported; Dental Prosthesis Design; Dental Abutments; Dental Occlusion; Maintenance; Survival;"* and *"Survival Analysis*". Titles yielded in the online search were screened for relevance, and full text was obtained where appropriate. A hand search was conducted in 3 peer-reviewed journals from 2000 onwards (Clinical Oral Implant Research, International Journal of Prosthodontics, International Journal of Oral Maxillofacial Implants). The authors then selected the most appropriate articles, giving preference to systematic reviews and long-term, patient-based data.

The PICO (Population, Intervention, Comparison, Outcome) question to focus the literature search was: "For patients presenting for replacement of a missing single-tooth with a single-tooth implant, what factors in the prosthetic rehabilitation optimize biological, technical and patient-related outcomes."

Population:	Patients presenting for replacement of a missing tooth.
Intervention:	Single-tooth implant.
Comparison:	Method of fabrication and design.
Outcome:	Optimized biological, technical and patient-related outcomes.

Table 2: PICO question to focus literature search.

This review focused on the prosthodontic component of implant therapy, and assumes that the implant has been placed in a prosthetically determined position. The prosthetic component has been divided into methods of provisionalisation, impression-taking, prosthesis design features and maintenance regimes. Thirty-nine articles were selected for scrutiny.

Results:

Provisionalisation:

The provisional restoration serves many purposes in implant rehabilitation. It provides patients with a quick and economical restoration of aesthetics and function, serves as a diagnostic template for the final restoration, and acts as a scaffold to guide soft-tissue contour for enhanced aesthetics(6). Provisional restorations vary in the origin of their support (tissue, tooth or implant-borne) and the timing of their installation.

If the provisional restoration is connected to the implant, the implant is invariably loaded. The original implant-loading protocol was drafted by P.I. Branemark in 1973(7). Its formulation was based on a historical understanding of bone biology and histology. It prescribed a three-month osseointegration period in the mandible, and a six-month osseointegration period in the maxilla. An increased osseointegration period was required for the maxilla due to poorer bone quality and quantity. The original protocol is regarded as the "gold standard" and has been practiced for many years with excellent results. Contemporary evidence is emerging that a three-six month period for osseointegration may not be required with a modified-surface implant, and different loading times between the arches may not be required due to an increased bone-to-implant contact(8). There is also emerging patient-based data that immediately provisionalised implants in certain clinical circumstances may perform as well as conventionally loaded implants.

An expert opinion by Santosa(6) described various proposals for provisionalisation. Provisional restorations are described according to the origin of their support, time of loading and occlusal contact. Immediately restored and immediately loaded restorations are fixed to implants within 48 hours of placement, however immediately loaded provisional restorations are in full occlusion within 48 hours of implant placement. Immediate provisionalisation offers the patient improved comfort and function during the implant healing period. The decision to make an immediate implant-borne provisional restoration is based on implant stability, bone quality and general site health.

An expert opinion by Castellon et al(9) discussed the modalities for immediate provisionalisation of single-tooth implants. The authors divided the aesthetic aspects of immediate provisionalisation into implant placement, abutment selection and preparation. They concluded that the benefits of immediate provisionalisation were maintenance of the interdental space, development the gingival sulcus, minimizing delay of the final restoration, improved patient comfort and elimination of second stage surgery.

In a narrative review, Chee (10) identified factors which determine implant aesthetics to include local anatomy, implant position and soft tissue management during the various phases of implant placement and restoration. Shaping of the peri-implant soft tissue begins immediately post-extraction, by the use of ovate pontics on RPDs/ FDPs, and develops through implant-borne provisional restorations. The author concluded that soft tissue aesthetics can be maximized through soft tissue manipulation in the provisional phase.

These three articles make strong, logical conclusions about provisionalisation, however no patient-based data is included to support their conclusions.

A case-control study by Degidi et al(11) compared immediate and delayed implant placement in 45 immediately provisionalised single-tooth implants in the aesthetic region. Statistically significant peak bone loss was associated in post-extraction sites compared to healed bone sites, however no significant correlation was found between bone loss and papilla growth. In the time following definitive restoration, the healed sites lost 0.16mm bone compared with the post-extraction group which lost 0.58mm bone. The authors concluded that immediate restoration did not appear to cause greater bone loss after the first year of function. While this moderate-sample size study demonstrates that immediate provisionalisation on implants is a possibility, there is no unrestored control group to determine if the impact of immediate provisionalisation was positive or negative.

A prospective case-series by Ferrara et al(12) reported the outcomes of 33 immediately-placed and provisionalised maxillary single-tooth implants over a 4-year observation period. If the papilla was present it was never lost, and patient satisfaction was high (average visual analogue scale (VAS) of 9.3/10). The authors concluded the aesthetic and functional results of immediately placed and restored maxillary anterior single-tooth implants were satisfactory, from patient and clinician perspectives. These results are weakened by the fact that 18% of implants could not be immediately restored and two implants of the remaining 27 failed to integrate.

A randomized control trial (RCT) by Lindeboom et al(13) compared immediately loaded with immediately provisionalised single-tooth implants in the anterior maxilla. 50 implants were placed and immediately provisionalised. Half the provisional restorations were restored in occlusion, while the other half were non-occluding provisional restorations. Two implants in the immediately loaded and 3 in the immediately provisionalised group failed; 13 of the remaining 45 implants showed loosening of the provisional crown, and 4 exhibited fracture of the provisional prostheses. The mean implant-stability quotient (quantification of osseointegration), marginal bone loss and gingival aesthetics for both groups were not statistically significant. The authors concluded that the occlusal status of the provisional restoration for a single-tooth implant did not affect clinical outcomes. This study of a moderate sized study group, has wide inclusion criteria, and there is no discussion of the status or role of the treating or reviewing clinician. Its high failure rate is of concern and indicates a need for further validated long-term clinical data.

Impression-Taking:

The goal of impression-taking is to accurately relate the position of the implant-head to the adjacent dental structures, and to transfer this information to a laboratory(14). An inaccurate impression is one of the factors that may contribute to prosthesis-misfit on issue.

Chee and Jivraj(14) discussed the impact of impression technique, implant componentry and impression material on master cast accuracy. The authors recommended fabrication of a custom impression coping to transfer vital information about peri-implant soft tissue contours which may be incorporated into the final prosthesis. The authors recommended use of an open custom tray, pick-up impression copings, and polyvinyl siloxane (PVS) material with adhesive for optimum impression accuracy. This review is clearly written with an evidence-based clinical recommendation, however, it fails to explain its search strategy, inclusion and exclusion criteria, and doesn't critique the evidence presented.

A laboratory study by Daodi et al(15) investigated the relative accuracy of different impression copings and elastomeric impression materials on implant position in a master cast. A Reflex microscope was used to measure dimensional discrepancy in three-dimensions against an aluminum measuring jig that fitted over the master cast. Implant-level impressions taken using repositioning impression copings demonstrated greater variation in analogue position in casts compared with impressions made using the pick-up impression copings. No difference in analogue position in casts was found between PVS or polyether(PE) impression materials.

Daodi et al(16) extended their first study to include an open-tray, pick-up impression coping splinted to the custom tray with Duralay. The authors found significant differences in the antero-posterior dimension with the repositioning impression technique, and in the mesio-distal and rotational dimensions with the unsplinted pick-up impression technique. No significant differences were found between the master-cast and the splinted pick-up group. It was concluded that connecting the impression coping to the impression tray with self-curing acrylic resin significantly improves the accuracy of the resultant casts. Both studies used a complex method to measure implant position and there was a lack of examiner blinding. While laboratory studies offer insight about the capabilities of a system, they do not guarantee clinical outcomes.

A laboratory study by Vigolo et al(17) compared positional differences between an acrylic resin master model and two single-tooth implant impression techniques. Forty pick-up implant impressions were taken in custom trays using PE impression material. Half the implant-impressions used a non-modified square impression coping and the other half used impression copings that had been sandblasted and coated with polyether adhesive. One blinded calibrated examiner performed all the measurements using a Nikon profile projector. The implant-impressions utilizing the modified impression copings showed significantly less measurement variability.

These authors(18) extended their first study to include the use of gold-machined UCLA abutments as impression copings. The castable portion was secured to the gold-machined portion with pattern resin and painted with polyether adhesive. The authors found the gold-machined UCLA abutments demonstrated reduced mean angular variations however statistical analysis indicated no significant differences between the median values of both groups. Both studies benefit from a large sample size, examiner blinding and good intra-examiner reliability. The measurement method was simple, only examined rotational positional changes, and only considered dimensional inaccuracy in one plane.

Implant-Abutment Connection:

Abutments may be connected to implants by different implant connection geometry. The “internal connection” is advocated to have reduced complications due to a more stable stress distribution throughout the body of the implant(19-23). The “external connection” has the advantage of a long history of excellent clinical service(24). While laboratory and finite element analysis (FEA) studies provide insight into the way a system works, the results do not necessarily correlate with clinical performance and need to be interpreted with caution.

An FEA study conducted by Merz et al(22) compared stress distribution of internal and external implant-abutment connections in simulated function. Implant specimens were cyclically loaded under wet conditions at 0°, 15 °and 30° off-axis. The same scenarios were recreated in an FEA model. Both connections demonstrated similar stress distributions when the implant-abutment was loaded axially. Off-axis loading produced reduced stress distribution to the implant threads for implants with an internal-connection, whilst higher tensile stresses were generated on the side facing the load in the screw threads of the external-connection implant. The authors concluded that the results of this study explain the significantly better long-term stability of internal hex abutment connection. The findings of the laboratory testing were not discussed, instead the article focused on FEA results. Claims about superior clinical performance of internal-connection implants were based on outcomes of different case-series studies, not comparative outcome studies.

A laboratory study conducted by Maeda et al(21) investigated stress distribution patterns between implants with an external hex or internal hex connection. Three implants were imbedded in an acrylic resin model and were restored with a 7mm high one-piece abutment. Three 120Ω strain gauges were attached to the implant surface. The specimens were loaded with a 30N force horizontally and vertically. The recorded strain values increased along the implant for both types of connections. Whilst data was not statistically significant between implant connections for vertical loading, horizontal loading produced a statistically significant increase with the external-type connection. The authors concluded that internal hex implants showed widely dispersed force distribution along that implant, compared with external connection. The validity of the testing methods was not discussed, nor the correlation of the experimental forces with those of clinical function.

A laboratory study conducted by Piermatti et al(23) investigated the effects of implant-abutment connection and screw design on screw tightness with long-term, off-axis loading. Ten 4mm×10mm implants from four implant systems (2 internal and 2 external connection) were embedded in resin models and cyclically loaded on the mesiobuccal cusp at 200N at a rate of 10Hz for one million cycles. The screw diameter and presence of a journal (smooth diameter machined on the end of a screw) was associated with maintenance of screw preload, whilst the implant-abutment junction was not a significant factor. The effect of using different implant systems with different design features may influence these findings.

Machtei et al(20) performed a retrospective, cross-sectional study to compare the periodontal health around teeth and dental implants with different restorative platforms. Twenty-eight of 73 implants were external hex, non-submerged placement, while the remaining 45 were internal connection with submerged placement. All implants had been in function for at least one year, with an average of 2.9 years. Compared with teeth, implants were associated with reduced plaque and gingival index, increased probing depth and greater bone loss. Significant positive correlations were found between IL-1 and TNFα levels and mean bone loss around teeth and implant sites. TNFα was significantly higher for the Morse-tapered implants, while for IL-1 and PGE_2 concentrations, no difference was noted between implant platforms. Bone loss was higher around the external hex connection, but not significantly different from the Morse-tapered implants. No statistically significant differences in clinical parameters and host response parameters were noted between implant platforms. The authors concluded that Il-1 and TNFα are sensitive markers for bone loss around teeth and implants. These results must be interpreted with caution, as authors did not consider other cofounding variables such as patient or site factors.

A review by Drago and O'Conner(19) discussed the biomechanics of an internal connection implant system, with an accompanying case-series study. Eighty-three internal connection implants were placed using a one or two-stage protocol in 45 patients. Other than one implant being lost due to trauma in an automobile accident, the author reported 100% cumulative survival rate with no reported prosthetic complications over an 18 month period. This study is a short duration case series of limited value with no control group, no information on blinding of clinicians, with outcomes of survival and complications considered.

A systematic review by Theoharidou et al(25) compared abutment screw-loosening in internal and external implant-abutment connections supporting single-tooth restorations. Clinical studies on single-tooth implants were included if they were of at least 3 years duration and reported on technical complications.

Twelve studies ranging 3-5 years in duration on 586 single-tooth external-connection implants and 15 studies on 1, 113 internal-connection implants were included in meta-analysis. The estimate percentage of complication-free single-tooth implants after 3 years was 97.3% and 97.6% respectively for external and internal connection implants. The authors concluded the geometry of the implant-abutment connection had no impact on the incidence of screw loosening. However, most of the included studies were conducted in a university setting, were not site specific and were of short duration. As a result they provide guarded conclusions on the long-term stability of various implant-abutment connections.

Abutment-Prosthesis Connection:

The choice of prosthesis retention remains a somewhat controversial issue. Some authors report that prosthesis retention has an impact on current and future implant service(26, 27). The major advantage of screw-retention is retrievability(27, 28), however the full benefit of retrievability over the long-term may not be seen in the short to medium-term, which is generally the duration of most studies(2).

In a narrative review, Chee and Jivraj(28) divided the issues arising from prosthesis retention into aesthetics, retrievability, retention, implant position, passivity of fit, provisional restoration, occlusion, loading, impression procedures and future treatment planning. The authors stated the major advantage of screw-retained restorations is retrievability. Concerns about a possible aesthetic compromise attributed to the screw access may be minimised with proper implant positioning and modern composite resins.

A review article by Hebel and Gajjar(26) discussed how screw-retained prostheses negatively affect occlusion and aesthetics. The authors report that the choice of cement vs. screw-retained implants has a major impact on the final occlusal design and directly affects the forces transmitted to the implant components and bone-implant interface. Other benefits of cement-retained prosthesis are reduced cost, reduced complexity of procedure, reduced chairside time and superior aesthetics. The authors report that cement-retained prostheses are retrievable if handled correctly, and conclude it is difficult to justify the use of screw-retained prosthesis except for limited abutment height. The occlusal theories put forward in this article are not supported by clinical data(5).

The review article by Michalakis et al(27) reported that cemented restorations are cheaper and easier to fabricate than screw-retained prostheses. The authors question the ability of cemented prosthesis to be predictably retrieved, and if a cemented prosthesis is selected, equigingival margins are recommended to allow complete cement removal. The authors concluded that clinicians should be aware of the limitations and disadvantages of each type of prosthesis and to make an informed choice by selecting the one that is most appropriate for each clinical situation.

A cohort study by Weber et al(29) compared peri-implant soft tissue between cemented and screw-retained single-tooth implants over a 3-year period. One hundred and fifty-two implants were inserted in 80 patients and a metal-ceramic crown was attached 3-5 months after surgery. All patients completed the study with no recorded prosthetic complications. The choice of prosthesis retention was decided by the dentist. Sixty-one point nine percent of screw-retained and 38.1% were cement retained. Cemented crowns showed increased bleeding scores, modified plaque index (MPI) and sulcus bleeding index (SBI) scores 6 months post-loading, while these variables improved over time in screw-retained crowns. While this study demonstrated a more favorable soft-tissue reaction to screw-retained prosthesis, overall SBI scores were low and no soft tissue recession was noted in either type of prosthesis. Patients were equally satisfied with the aesthetics of either type of crown, whilst the clinicians favored the aesthetics of cemented prosthesis.

Vigolo et al(30) conducted an RCT to compare peri-implant soft and hard-tissue and prosthetic complications between cement and screw-retained single-tooth implant-crowns over a 4 year period. Twenty-four implants were placed in 12 patients with bilateral edentulous sites, and were restored 5 months post-insertion with metal-ceramic crowns. All patients were present at the four-year recall with no reported prosthetic or biological complications. No significant differences between the two types of prosthesis connection were reported concerning plaque accumulation, inflammation, mean probing-depths and BOP. The authors concluded there was no indication that one method of retention was clinically or biologically superior. Despite low subject numbers and a moderate follow-up time, a within-subject comparison is an appropriate control.

Prosthesis Materials:

An implant can be attached either directly to single tooth prosthesis or via an intermediate abutment. In submerged implant placement, the abutment is in intimate contact with peri-implant soft tissues, hence maximizing abutment biocompatibility is important. Despite an excellent record of gold and titanium abutments(24), there is a strong trend towards metal-free dentistry driven by consumers and companies.

Linkevicius et al(31) wrote a systematic review on the impact of abutment material on peri-implant tissue stability. A meta-analysis could not be performed because of the variation of experimental design, however the authors concluded that there is no evidence to definitively state that titanium abutments perform better in maintaining stable peri-implant tissues compared with gold, aluminum oxide and zirconium oxide materials.

A prospective case-series by Glauser et al(32) evaluated peri-implant hard and soft tissue reaction to zirconia abutments in the aesthetic zone. Fifty-four single-tooth implants were restored with zirconium abutments and all-ceramic crowns (ACC). Fifty-three restorations were available for review at one year and 36 (66%) were available at 4 years. All reviewed restorations were in place with no signs of chipping or fracture. Two restorations showed screw loosening over the 48-month period – one of which necessitated destruction of the crown to access the screw channel. No statistically significant differences were noted for gingival or plaque index when implant sites and neighboring teeth were compared at the 0, 12 or 48 month reviews. Radiographic examination revealed a 1.1mm and 1.2mm bone loss at the 12 and 48 month recalls respectively. The authors concluded that Zirconia is a suitable material for implant-supported single-tooth reconstructions in incisor and premolar locations. This study had a high dropout rate, vague inclusion criteria, modest sample size, no information on treating or examining clinicians and no criteria for aesthetic evaluation.

Canullo's(33) prospective cohort study evaluated clinical performance and marginal fit of customized zirconia abutments. Thirty implants were restored with either an all-zirconia abutment, or if the author judged the peri-implant sulcus to be deep, a zirconia abutment with a metal collar at the implant-abutment junction. Scanning electron microcopy (SEM) demonstrated extremely low marginal gap values for both types of abutments (average horizontal gap 10.161μm; average vertical gap 4.783μm). No abutment fracture or screw loosening were reported during 40-months observation, resulting in a cumulative survival rate of 100%. There were no statistically significant differences for periodontal indices when implant sites were compared with neighboring teeth at baseline or follow-up. The author concluded that titanium-zirconia abutments might be comparable with currently available aesthetic implant abutments.

An RCT by Vigolo et al(34) compared peri-implant soft and hard-tissue responses to gold or titanium abutments with single-tooth implants. Forty implants were placed in 20 patients with a missing single-tooth on both sides of the mouth. The implant was restored with either a titanium abutment or a machined gold UCLA abutment. Metal-ceramic crowns (MCC) were cemented 1mm subgingivally with temporary cement and 100% of subjects were present at the 4-year recall, and no prosthetic complications were reported. No statistically significant differences were found in supragingival plaque, gingival inflammation, bleeding on probing, probing depth, keratinised mucosa, or radiographic bone levels between abutments. The author concluded that there is no evidence that either titanium or gold alloy abutments were clinically or biologically superior. This study is a well-designed split-mouth RCT with long-term follow-up and adequate sample size.

Degidi et al(35) conducted an RCT to compare immunohistochemical markers in peri-implant soft tissues around titanium and zirconia. Ten implants were placed in 5 patients, and restored with either a titanium or zirconium healing-cap and gingival biopsy was obtained at 6 month and examined for biochemical markers. Tissues around titanium healing caps showed higher rate of inflammation when compared with the peri-implant tissues around zirconium healing caps. Titanium healing caps were associated with a higher expression of nitric oxide synthase 1 and 2, indicating an increased bacterial count. The titanium and zirconium oxide surfaces were of equal roughness under SEM; however the titanium specimens were uniformly coated with bacterial biofilm, while the zirconium healing caps were characterized by clusters of bacteria. The authors suggest that zirconia elicits a superior biological response due to reduced bacterial accumulation. This is a well-designed, split-mouth study, with a clearly defined inclusion criteria and objective outcomes.

In the RCT by Andersson et al(36), 89 fixtures were restored with either alumina or titanium abutments and a cemented crown. Whilst 100% of the implant fixtures survived over a 12-36 month observation, 5of 34 ceramic abutments fractured during the preparation and placement and a further 2 of 34 during function. No titanium abutment failure was noted. Similar gingival responses were observed between abutments and no bone loss was measured over the review period. One-hundred percent of patients and 97% of clinicians for the test and control groups rated aesthetics as excellent or good. The authors concluded that ceramic abutments are more sensitive to handling procedures than titanium abutments. However, this study does not have a well-defined treatment protocol, there is no discussion on surgical procedure or treating or examining clinicians, and the varied follow-up between centers is a cofounding variable.

Occlusal Scheme:

Concepts of "dental occlusion" are ever evolving in Prosthodontics(5), and implant dentistry is no exception. Occlusion in implant dentistry can be divided into both occlusal scheme and timing of occlusal contact from implant placement(37). There is pressure from consumers to deliver the final prosthesis as soon as possible, and strong recommendation from implant companies and reputed clinicians that "immediate loading" is an acceptable treatment modality.

Klineberg et al(5) conducted a systematic review to determine if occlusal design of fixed and removable prosthesis has an impact on clinical outcomes. There is no evidence from long-term outcome studies to specify a particular occlusal design for optimizing clinical outcomes for implant superstructures. Neurophysiological evidence indicates the masticatory system adapts to subtle and gross changes in the occlusal status. The authors recommend axial loading of implants by cradling supporting cusps in the opposing tooth central fossa, reduced cuspal inclination and wide grooves and fossa. Single-tooth implant crowns should demonstrate shimstock (10µm) clearance at intercuspal position and centric occlusion. Posterior contact on excursive movements are discouraged.

A review by Taylor et al(38) examined the evidence of occlusal principles for removable and implant-borne prosthesis. Axial loading of implant-borne FDPs has been promoted, and animal studies have failed to demonstrate a negative affect on peri-implant bone levels after extended periods of non-axial loading. Furthermore, the geometry of implants and forces of occlusion during mastication are rarely axial. The concept of progressive loading of dental implants has not been substantiated in animal studies, and the authors doubt that progressive loading can be realistically achieved. No clinical data was found to support the proposal that modifications to the dimensions and occlusal contacts or anatomy of prostheses can reduce loading on implants. The authors concluded that little scientific evidence exists to support a direct cause-effect relationship between occlusal factors and deleterious biological outcomes for implants.

Esposito et al(39) conducted a systematic review of RCTs to compare clinical performance of implant-borne prostheses with time to loading. Eleven RCTs on 790 implants were included in this study, with roughly one third in the immediate, early and conventionally loaded groups. No significant differences for prosthesis failure, implant failure or for marginal bone level changes were associated with the time of loading. The authors concluded "while it is possible to successfully load dental implants immediately or early after their placement, not all clinicians may be able to achieve optimal results", and a high insertion-torque value is a pre-requisite for success with immediate loading. While a Cochrane systematic review represents the highest level of evidence due to rigorous methodology, these conclusions are ambiguous and do not guide clinicians under which conditions immediate loading might be suitable.

Glauser et al(40) systematically reviewed marginal soft tissue response to immediately-loaded or immediately-restored implant restorations. Seventeen clinical studies were included, however a meta-analysis could not be performed due to data heterogeneity. Clinical studies on fixed reconstructions (n=12) demonstrated no difference in gingival inflammation between immediately loaded vs. immediately provisionalised implants. The authors found no evidence to suggest deleterious peri-implant mucosal complications to be attributed to immediate-loading or restoration protocols. An average recession between 0.5-1mm after 12 months was noted in most cases. The authors concluded that once immediately loaded or restored implants integrate, they appear to show a soft-tissue reaction comparable to those of conventionally loaded implants. It should be noted that included studies suffered from short follow-up and small numbers of patients and/or implants, and most studies lacked comprehensive documentation on marginal soft tissue aspects.

Henry and Liddelow(37) reviewed data to provide evidence-based guidelines for successful immediate loading of dental implants. The literature demonstrated a wide variance in the definition of "immediate loading" from both timing and occlusal scheme perspectives. Success with immediate loading was attributed to primary stability, modified implant surfaces and controlled functional loading of the implant interface. The authors made several recommendations based on the literature, including:

- Inexperienced operators should utilize conventional loading protocols if conditions are not optimal.

- Patient-mediated factors such as systemic diseases or medications compromise bone healing; diabetes, parafunction and smoking should be regarded as contra-indications to immediate loading.
- Implants must achieve an insertion torque of at least 32Ncm and a resonance frequency analysis (RFA) of at least 60 ISQ to be immediately loaded.

They authors concluded that although there are some promising clinical results, immediate loading should be considered on an individual basis for selected cases only.

Donati et al(41) conducted a prospective RCT to evaluate the outcome of immediate loading of single-tooth implants. 161 patients with a healed extraction site were randomized to receive a single-tooth implant by one of three installation procedures: two stage installation with conventional loading (control group), conventional placement with immediate loading (test group 1) and osteotome placement with immediate loading (test group 2). Patients were excluded if the implant was not completely encased in bone, or an insertion torque of at least 20N could not be achieved. Patients were examined clinically and radiographically at 3 and 12 months after implant. Three of 54 test implants placed using an osteotome technique and 1/50 test implants placed using a conventional technique failed to integrate within the first three months after placement. No failures were noted in the control group. No statistical difference was found between groups in terms of clinical or radiographic variables, with similar bone levels between the 3 and 12 month recalls. The authors concluded immediate loading of single-tooth implants placed with a conventional installation technique with sufficient primary stability may be considered as a valid treatment option.

Clinical Outcomes and Maintenance:

Implants have clinically acceptable longevity, however a recent meta-analysis of implant survival has linked implant-borne prostheses with a higher level of biological and technical complications when compared with tooth-borne FDP(2). Early detection of current and future problems is the key to prevention(42) and clinicians need an understanding of possible complications. It is prudent to have a sound knowledge of survival data on single-tooth implants to inform patients pre-operatively of the average longevity and what maintenance may be required.

Jung et al(3) conducted a systematic review on the survival and complications of single-tooth implants after 5 years of function. Twenty-six clinical studies on 1558 implants were included. Meta-analysis revealed 1.9% of implants were lost before functional loading, followed by an estimated annual failure rate after loading of 0.28%. The estimated survival rate after 5 years for implants supporting single crowns was 96.8%. Half the included studies reported on the survival of the reconstructions, giving an estimated 5-year survival rate of 94.5%. The survival rate was lower for all-ceramic crowns (ACC - 91.2%) when compared with MCC (94.5%). Half the prosthetic failures included failure of the implant as well.

Pjetursson et al(2) conducted a systematic review to compare the survival and complication rates of FDP on teeth and implants. Similar 5 and 10 year survival rates were found for single tooth implants (94.5% and 89.4%) and FDP on teeth (93.8% and 89.2%), however and increased rate of complications was noted with implant-borne restorations. The most frequent technical complication was fractures of the veneer material (ceramic fractures or chipping), abutment or screw-loosening and loss of retention. The authors concluded that planning of prosthetic rehabilitations should preferentially include conventional tooth-supported FDPs, solely implant-supported FDPs or implant-supported single crowns.

Both aforementioned meta-analyses(2, 3) are very strong pieces of evidence, however must be interpreted with caution as included studies did not necessarily report on the same outcomes or use a standardized method of assessment. Also surgical and restorative protocols differed between studies and there was no breakdown of the analysis according to patient or site-specific factors.

Bragger et al(43) conduced a prospective case series study to assess the incidence of technical and biological complications on implant and implant-tooth borne FDP over a ten-year period. Eighty-nine of the original 127 patients were available at the ten-year recall. Ten percent of the soley-implant supported FDPs failed over the ten-year period and 66.5% implant-borne single-crowns were complication-free over the observation period. Implants treated for peri-implantitis and FPDs exposed to either technical or biological complications were more likely to fail compared with FPDs without preceding complications. Although this study presents only a small sample of implant-borne single-crowns, it contains long-term data from which single-tooth implant data can be identified. However, data is extrapolated from a heterogeneous group of restorations and does not specify site, implant or patient-specific factors.

Lang et al(4) wrote a consensus statement on implant and implant-borne FDP survival and complications to formulate clinical recommendations for monitoring peri-implant soft-tissue conditions. Based on 8 clinical studies, the group found that early loss of implants supporting single crowns is 0.5% before prosthetic reconstruction, and 2-2.5% within the following five years, and peri-implantitis and soft tissue complications for the implant-supported FDP occurred in 8.6% of implants after 5 years. The authors recommend monitoring peri-implant conditions through periodic oral hygiene checks, light peri-implant probing (0.25N force) and noting incidence of bleeding on probing; and they recommend systematic and continuous monitoring of peri-implant tissue conditions for monitoring peri-implant health and disease.

Heitz-Mayfield(42) conducted a systematic review to provide clinical guidelines for diagnosis and risk assessment of peri-implant disease. Serial Peri-implant probing was found to be a reliable and sensitive tool for diagnosis peri-implant health and disease. If probing with a light force (0.25N), complete mucosal seal was achieved within 5 days. Absence of bleeding on probing was associated with stable implant conditions. While conventional periapical radiographs are a useful tool for monitoring and documenting peri-implant bone level at one time, they are limited in being unable to measure bone height buccally or lingually, and underestimate disease. Tomographs are unable to measure subtle changes in bone height due to distortion and poor resolution. Implant mobility represents a complete loss of osseointegration, hence is not a useful tool for early diagnosis of peri-implant disease. The author concluded that peri-implant probing depths, bleeding on probing, oral hygiene and radiographs on an individual basis are suitable measures of peri-implant status. This article has the strengths of a systematic review structure, and supporting evidence is critiqued.

Table 3. Selected studies of best evidence in order of topic and study design:

Prosthetic facet	Best evidence data	Study Summary	Outcomes	Comments
Provisionalisation	Lindeboom et al 2006	• **Level 1b: Randomised control trial** • 50 implants were placed in the maxillary anterior region and immediately provisionalised • Implants were randomised to receive a provisional restorations in or out of occlusion • Definitive restorations was fabricated 6 months after implant placement • Patients were monitored for 12 months	• 2/25 implants in the immediately loaded group and 3/25 implants in the immediately provisionalised group were lost • 13/45 remaining provisional restorations experienced screw loosening and 4 had fracture of the provisional prosthesis • No significant differences in mean implant stability quotient, marginal bone loss or gingival aesthetics was observed between groups	• Short-term data • Moderate subject numbers • Wide inclusion criteria • No description of examining or treating clinicians
Impression-taking	Daodi et al 2001	• **Level 4: Laboratory study** • 40 single-tooth implant impressions were taken of a maxillary acrylic resin model with an implant placed in the #11 site • 20 utilised an open tray impression coping and 20 utilised a closed tray impression coping • Half the impressions were taken using polyether impression materials, and the other half were taken using polyvinyl-siloxane impression material • Antero-posterior position, mesio-distal position and axial rotation was measured using a reflex microscope	• Impression material was not a significant factor for any of the measured variables • The antero-posterior dimensional error was twice that for the repositioning technique than for the pick-up technique • Axial rotation and inclination values ranged and differences were not significant • The repositioning impression technique showed more variation in the position of the abutment/ implant analogue assembly in resultant casts when compared with the pick-up impression technique	• Laboratory results ignore the tolerance in the biological system, hence the clinical significance of the results is uncertain • Examining clinician not blinded to the type of impression coping used • Complex measurement technique
	Vigolo et al 2000	• **Level 4: Laboratory study** • 40 single-tooth implant impressions were taken of a maxillary acrylic resin model with an implant placed in the #15 site • 20 utilised an unmodified open tray impression coping (Group A) and 20 utilised a open tray impression coping that had been sand-blasted and coated with adhesive (Group B) • All impressions were taken using	• Statistical analysis found no significant differences between the medians of both groups • Group B showed significantly less measurement variability • Group A maximum angular variation 3 degrees and 38 minutes • Group B maximum angular variation 1 degree and 0.2 minutes • The rotational position changes of the	• Laboratory results ignore the tolerance in the biological system, hence the clinical significance of the results is uncertain • Complex measurement technique • Study only examined inaccuracy of

		polyether impression material in custom trays • A single-blinded operator assessed accuracy by the two angles formed by the molar plane and the distopalatal side of the implant hexagon (MIA), and the premolar plane and the mesiopalatal side of the implant hexagon (PIA)	hexagon on implant replicas were significantly less variable in the master casts obtained with the modified impression copings than those of non-prepared copings	impression coping in the rotational dimension
Implant-abutment connection	Theoharidou et al 208	• **Level 1a: Systematic review** • Systematic review of clinical studies reporting on clinical performance of internal and external connection of implant systems supporting single-crowns • Clinical studies were included on single-tooth implants that reported on mechanical complications with a minimum observation of three years • 27 studies were included in the final analysis	• 12 studies contained implants with an external connection; 97.3% of single-tooth implants were free of prosthetic complications after 3 years of clinical service • 15 studies contained implants with an internal connection; 97.6% of single-tooth implants were free of prosthetic complications after 3 years of clinical service	• Assumption that the implant-abutment junction is responsible for prosthetic complications • No differentiation according to site of mouth • Short follow-up time. • No standardisation amongst included studies
	Mertz et al 2000	• **Level 4: Laboratory study/ Finite element analysis study** • Internal and external connection implants were embedded in acrylic resin and restored with a steel crown • The model was exposed to cyclic loading under wet conditions at 380N axially, 15° and 30° off-axis • The same complex was created in a finite element analysis model	• When axially loaded, stress distribution is symmetric and stress levels are low on all parts for both connections • When loaded 15° off-axis higher tensile stresses in the screw threads on the side facing the load with an external connection, whilst the majority of the load transfer is taken up through the tapered connection in an internal connection implant • When loaded 30° off-axis areas of stress beyond the cyclic strength are no longer small, such that no supporting effects can be claimed with an external connection. An internal connection implant demonstrates increased stresses, however the majority of this is taken up through the tapered connection	• Protocol unclear • Number of specimens/ testing regime unclear • Outcome of cyclic loading of the resin model not discussed • Laboratory results ignore the tolerance in the biological system, hence the clinical significance of the results is uncertain

Prosthesis retention	Weber et al 2006	• **Level 2b: Cohort study** • 152 single tooth implants were placed in the anterior maxilla in 80 patients • Choice of prosthesis retention was decided by treating clinicians • Patients were monitored clinically for 36 months	• All patients completed the study with no prosthetic complications reported • Peri-implant soft tissues responded more favourably to screw-retained crowns when compared with cement-retained crowns • No soft tissue recession was noted in either types of crowns • Patients were equally satisfied with the aesthetics of either type of crowns	• Allocation of retention system left up to treating clinician • Treating and evaluating clinician are the same • Relatively short follow-up time
	Vigolo et al 2004	• **Level 1b: Randomised control trial** • 12 patients with a bilaterally missing tooth were treated with single-tooth implants • Each site was randomised to receive either a screw or cement retained prosthesis • Patients were examined clinically and radiographically	• All patients completed the study with no prosthetic complications reported • Plaque was present on 13% of evaluated sites, however inflammation was noted adjacent to 4.3% screw retained crowns and 4.4% cement retained crowns • Mean probing depths of 2.8mm was noted adjacent to both types of restorations • Low percentage of bleeding on probing sites was noted 7.2% of sites • No significant differences were revealed between the two groups	• Small subject sample • Treating and evaluating clinician are the same • Relatively short follow-up time
Abutment material	Linkevicius et al 2008	• **Level 1a: Systematic review** • Systematic review of the stability of peri-implant tissues between titanium abutments versus gold alloy, zirconium oxide or aluminum oxide abutments • Included animal and human studies, must be controlled and at least 12 months duration • 9 studies included	• Animal histological studies revealed marked soft tissue recession around gold alloy abutments in one study on 5 dogs • This was refuted by another animal study by the same group 10 years later • One human study demonstrated no difference in the peri-implant tissues between gold and titanium abutments. • Histological studies revealed similar peri-implant tissue composition between titanium and Alumina, with a reduced inflammatory infiltrate around zirconia • 3 studies comparing Aluminum oxide with titanium revealed contradictory results in bone loss between abutments. A five-year follow up study noticed more frequent soft tissue recession.	• Limited by the evidence available • No standardisation between included studies

	Vigolo et al 2006	• **Level 1b: Randomised control trial** • 20 patients with bilaterally missing single-tooth had 40 implants placed • Sites were randomised to receive either a titanium or gold abutment • Patients were monitored clinically and radiographically for 4 years	• All patients completed the study with no prosthetic complications reported • At the four year evaluation gingival inflammation involved 4.7% of the titanium and 4.5% of gold crowns • A mean probing depth of 2.8mm and mean marginal bone loss was 0.4mm (range 0.3-0.8mm)was recorded for both types of restorations • 6.8% of sties exhibited bleeding on probing • No significant difference between the two groups	• Examining clinician not blinded to abutment material • Extent of the tolerance in the human system not discussed (i.e. both titanium and zirconia exhibit excellent biocompatability clinically)
	Degidi et al 2006	• **Level 1b: Randomised control trial** • 5 patients had 10 implants placed • Implants were randomised to receive either a titanium or zirconia healing cap • Peri-implant soft-tissues were evaluated at 0 and 6 months clinically and radiographically • Healing abutment surface was examined under SEM for bacterial colonisation • A gingival biopsy was taken at each site at 6 months post insertion	• PPD<3mm for both groups • Titanium surfaces appeared to be uniformly coated with biofilm, while zirconium samples were characterized by clusters of bacteria • The inflammatory infiltrate was mostly present in the titanium specimens, with larger extension than in the zirconium specimens • Statistically significant differences were found in microvessel density between group I and II • Statistically significant differences were found in low and high intensities of NOS1, NOS3 and VEGF. The high intensity were mostly expressed in the titanium group while the low intensity were mostly expressed in the zirconium oxide group • Tissues around titanium healing caps underwent a higher rate of inflammation	• Immunohistochemistry may have a questionable correlation with biological reaction • Extent of the tolerance in the human system not discussed (i.e. both titanium and zirconia exhibit excellent biocompatibility clinically)
Occlusal scheme	Klineberg et al 2007	• **Level 1a: Systematic review** • Systematic review of clinical studies on occlusal design of removable and fixed prosthodontics, and whether occlusal design affects diet, quality of life, bruxism and attrition	• There is no research evidence form long-term outcome studies to specify a particular occlusal design for optimizing clinical outcomes for implant superstructures • Long-term clinical outcome studies on	• Limited by evidence available • No standardisation between included studies • Clinical guidelines are

		• Clinical studies and systematic reviews on occlusal schemes in removable and fixed prosthodontics were included • 114 studies were included	implant-supported FDP in the mandible have indicated that an association of occlusal loading with occlusal design was of minor or no importance to marginal bone loss, and the key cofounding variables were smoking and plaque control, which were directly related to alveolar bone loss	not directly supported by clinical outcome data
	Esposito et al 2007	• **Level 1a: Systematic review** • Systematic review of immediate, early and conventional loading of implant-borne prostheses over a 6-12 month period • RCTs were included with a minimum of 6 months observation • 11 studies were included	• A total of 790 implants were placed in 300 patients • 6 studies compared immediate with conventional loading, 3 of which were on single tooth replacement • 2 studies compared early with conventional loading • 2 studies compared immediate with early loading • No significant differences for prosthesis failures, implant failures or for marginal bone level changes for loading method	• Limited by evidence available • No standardisation between included studies • No clinical guidelines
	Glauser et al 2006	• **Level 1a: Systematic review** • Systematic review of marginal soft tissue aspects at implants subjected to immediate loading or immediate restoration • Human studies with follow up >12 months were included and restored within 24 h of placement • 17 studies were included	• No differences in gingival inflammation between immediate and late loading • Variable results in aesthetic outcomes • Average recession between 0.5-1mm after 1 year • Once immediately loaded or restored implants integrate successfully, they appear to show a soft-tissue reaction comparable to those of conventionally loaded implants	• Limited by evidence available • No standardisation between included studies • No clinical guidelines
Clinical performance	Jung et al 2008	• **Level 1a: Systematic review** • Meta-analysis of clinical studies to assess the 5-year survival and complications of implant-supported single crowns • Studies where data on survival and complications of single-tooth implants with a minimum 5 year observation were included • 26 studies were included	• Estimated survival rate after 5 years for implants supporting single crowns was 96.8% • 1.9% implants lost before functional loading • Estimated annual failure rate after loading was 0.28% • Estimated survival rate after 5 years for implant-supported single crowns was	• Limited by evidence available • No standardisation between included studies • No differentiation into different sites in the mouth

			94.5% (95.4% for MCC and 91.2% for ACC) • Estimated cumulative rated of various peri-implant mucosal lesions after 5 years was 9.7% • Cumulative rate of crowns having an unacceptable or semi-optimal aesthetic appearance was 8.7%	
Maintenance	Heitz-Mayfield 2008	• **Level 1a: Systematic review** • Systematic review to provide clinical guidelines for diagnosis and risk assessment of peri-implant disease	• Probing using a light force (0.25N) does not damage the peri-implant tissues • An increase in probing depth over time is associated with loss of attachment and supporting bone • Bleeding on probing indicates presence of inflammation in the peri-implant mucosa • Radiographs are required to evaluated supporting bone levels around implants. • There is significant evidence that poor oral hygiene, a history of periodontitis and cigarette smoking are associated with peri-implant disease • There is limited evidence that diabetes and alcohol consumption are associated with peri-implant disease • There is conflicting evidence that genetic traits and a rough implant surface are associated with peri-implant disease	• Limited by evidence available • No standardisation between included studies • Methodology not sufficiently detailed

Discussion:

The strength and quality of evidence to support clinical decision-making in single-tooth implant rehabilitations depends on the facet examined. Strong opinion prevails in all aspects of implant dentistry, whether substantiated by published clinical data or not. No published studies are infallible; even meta-analysis of data, which draws its strength from increased numbers of samples, but suffers from discrepancy in study variables. Few studies report on patient-based outcomes, and no reviewed studies examined patient-based outcomes other than aesthetics. Despite the weaknesses in the evidence, it is better to approach clinical treatment with knowledge of the limitations of the evidence-base, as opposed to a state of ignorance. The object of this review is to assess the strength of the available evidence and identify facets of implant rehabilitation that result in superior clinical and patient-based outcomes.

The evidence supporting provisionalisation of single-tooth implant restorations is generally poor in quantity and quality. No studies were found comparing outcomes from provisionalisation on implants with tissue or tooth-borne support. The literature suggests that the soft-tissue profile of the definitive restoration can be optimised using implant-borne provisional restorations. However there are no clinical trials to demonstrate this, or prove superior aesthetic outcomes compared with completion of the final prosthesis in the absence of provisional restorations.

Several laboratory studies have addressed the relative accuracy of impression taking in implant dentistry. Under laboratory conditions, an elastomeric impression material used in conjunction with a pick-up impression coping, ensures a high degree of implant-impression accuracy. All aspects of prosthesis fabrications introduce some dimensional discrepancy, and there is emerging evidence that biological tolerance occurs(5, 27), however the limits of this are unknown. No patient-related data were found, hence the clinical implications of the dimensional discrepancies between impression taking methods is unknown.

The majority of the evidence on implant connections was from laboratory studies or FEA. While they may contribute to our understanding of the biomechanics of the implant connection, it is difficult to extrapolate clinical performance unless derived from long-term clinical data. While the evidence suggests that implants with internal connection offer superior stress distribution with off-axial loading(20-22), the clinical evidence comparing both systems is lacking.

Prosthesis retention remains a passionate topic in the implant literature. Narrative reviews suggest that the choice between cement- or screw-retained FDP has an impact on prosthesis function, however clinical studies reveal no differences biological, technical or in patient-related outcomes(2, 29, 30). The need for removal and reseating of the implant-borne restoration is a strong philosophical argument in favour of screw-retention, but this is difficult to demonstrate from short to medium-term clinical studies.

There is strong evidence from human and animal-based clinical data that all commercially available abutment materials offer excellent biocompatibility(31, 34, 35). Gold and titanium are the traditional materials which have a long history of satisfactory clinical service(24). There is emerging evidence that Zirconia provides superior biological response(31-33, 35), however medium- to long-term data is lacking to substantiate its comparative clinical service. It is apparent that Alumina is an inappropriate material for posterior abutments due to its comparative fragility(36).

Occlusal design for implant-borne superstructures concerning type and timing of loading is a controversial topic in implant dentistry. Clinical guidelines are extrapolated from studies on tooth and tissue-borne prostheses, however no evidence has been linked to improved clinical outcomes from a specific occlusal design(5). Timing to loading is a well-studied area with multiple systematic reviews and RCTs. Meta-analysis is generally not attempted, as it is difficult to control the various confounding factors between the designs of clinical studies. While there are some promising clinical results, immediate loading should be considered on an individual basis for selected cases only(37, 39).

Outcome studies define a "successful prosthesis" to be one that is functioning over the observation period without complications. A "surviving prosthesis" is one that has suffered complications, however is still in situ(3). The literature suggests that implant-borne FDP are associated with a higher degree of biological and technical complications when compared with tooth-borne FDP(2). However it must be interpreted with caution, as the same complications occurring on either a tooth or implant-borne FDP may not be of comparable importance. For example, a porcelain fracture on a screw-retained single-tooth implant is easily retrieved and repaired, whilst a porcelain fracture of a tooth-borne cemented FDP is not easily retrievable. Clinicians need an understanding of what can go wrong, and be aware of specific and sensitive markers to identify peri-implant disease. Patients should be informed of the spectrum of potential complications that can occur with implant-borne prostheses, and their associated future costs. Patient-associated risk-factors which might pre-dispose a patient to increased likelihood of complications should be identified prior to commencement of treatment.

Conclusions:

- There is no clinical evidence to suggest that any form of provisionalisation yields superior clinical outcomes. It may be useful to mould soft-tissue, and psychologically condition the patient for the definitive restoration through the use of implant-borne provisional restorations.
- A pick-up impression coping in conjunction with an elastomeric impression produces the highest implant impression accuracy. No difference in implant position accuracy was found between elastomeric materials.
- There is evidence from laboratory and FEA studies that implants with an internal-type connection exhibit better stress distribution with off-axis loading. There is inadequate clinical evidence to suggest superior clinical outcomes with different implant connection geometry.
- Short to medium-term clinical data show no statistically significant differences between prosthesis retention mechanism. In view of potential complications that may occur over the lifespan of a prosthesis, the authors of this review favour screw-retention because of its predictable retrievability.
- All commercially available abutment materials exhibit a satisfactory biological response. Long-term clinical data on the performance of Zirconia as a substructure for single-tooth implants is lacking.
- There is no clinical data comparing implant-occlusal schemes relative to clinical outcomes. Off-axis loading and shimstock clearance at intercuspal position and centric occlusion is recommended.
- Whilst a conventional loading protocol of 3-6 months undisturbed osseointegration is the "gold standard", there is emerging evidence that a modified surface implant may achieve satisfactory osseointegration in 6 weeks. Further long-term clinical studies are required before definitive conclusions can be made about times to loading. Some clinical studies exist to suggest that immediate loading through implant-borne provisional restorations may result in similar implant survival and

superior aesthetics. However all data cautions that immediate-loading should only be conducted by experienced operators with a sound-knowledge of bone-biology.

- Single-tooth implants offer comparable if not superior clinical service to FDP on teeth and do not compromise adjacent abutment teeth. There is strong suggestion from clinical data that implant-supported FDP are associated with increased risk of complications compared with tooth-borne solutions(2). Patients undergoing implant therapy must be advised of the risks and future complications that may occur prior to undertaking implant therapy.
- Systematic and continuous monitoring of peri-implant tissue conditions is recommended for the diagnosis of peri-implant health and disease. Serial peri-implant probing depths, bleeding on probing, oral hygiene and radiographs on an individual basis are suitable measures of peri-implant status.

Appendices:

Installation instructions:

The files for the multimedia educational module are stored on the CD at the end of this thesis. They can be viewed on any iPhone, iTouch or computer with iTunes installed.

- Install the latest version of iTunes (located at http://www.apple.com/itunes/download/)
- Run the iTunes program
- Drag the contents of the CD into the "my videos" section under "my library"
- You can watch the videos either within the iTunes program itself, or on a multimedia device by syncing the device with iTunes.

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