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# Reconstructive aspects: Summary and consensus statements of group 3. The 5th EAO Consensus Conference 2018

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## Abstract

**Objectives**: The tasks of this working group were to evaluate the existing evidence on the efficiency and efficacy of the digital and conventional workflows for the fabrication of fixed implant reconstructions, to assess the performance of all-ceramic fixed implant reconstructions and, finally, to evaluate the outcomes of internally and externally connected implant abutments and reconstructions.

**Methods**: Four reviews were available analyzing the current literature on the respective topics. One review dealt with the efficiency and efficacy of digital and conventional fabrication workflows. Two reviews analyzed the outcomes of all-ceramic fixed implant reconstructions, one focusing on single-implant reconstructions and the other evaluating multiple-unit implant fixed dental prostheses (FDPs). The fourth review evaluated the clinical outcome on external, respectively, internal

implant-abutment connections. These reviews were the basis for the discussions within the group and at the plenary sessions.

**Results**: The present consensus report gives the consensus statements, the clinical recommendations, and the implications for future research as discussed and approved by the plenum of the consensus conference. The four manuscripts by Mühlemann et al., Rabel et al., Pieralli et al., and Pjetursson et al. are published as part of the journal supplement of the present EAO consensus conference.

**KEYWORDS**

all-ceramic, conventional workflow, digital workflow, fixed dental prostheses, full-arch, implant reconstructions, lithium disilicate, optical impressions, single crown, zirconia

## 1 | INTRODUCTION

Fixed implant reconstructions are a frequently applied means for the replacement of single and multiple teeth today. The outcomes of the fixed implant single-unit and multiple-unit fixed implant reconstructions have been evaluated in systematic reviews at consensus conferences in the past with the aim to provide clinical guidelines and recommendations for the clinicians. In general, good outcomes for both implant single crowns (SC) and multiple-unit fixed dental prostheses (FDPs) were reported. These results, however, mostly included metal-ceramic reconstructions made with conventional laboratory fabrication procedures. Very limited information was available on all-ceramic implant FDPs.

In recent years, numerous new technological developments have been introduced, significantly changing the fabrication workflows and prosthetic options of the different implant reconstructions. While the conventional workflows include conventional impression of the implant site using traditional impression trays and elastomeric impression materials and manually made fabrication of the implant reconstruction in the dental technical laboratory, the more recent digital workflows start with intraoral optical impressions, followed by CAD/CAM procedures for the fabrication of the reconstructions in the dental technical laboratory. These recent developments led to significant changes of the way clinicians and technicians approach the patient situations. In addition, new restorative materials like the ceramics zirconia and lithium disilicate were introduced, delivered as industrially made ingots to be processed with CAD/CAM procedures.

Hence, the decision-making process between the different workflows and the different restorative materials is becoming more and more complex for the restorative team and new guidelines and recommendations are needed.

Fixed implant reconstructions can be connected to the respective implants by means of external or internal implant-abutment connections. The type of implant-abutment connection may have an influence on the stability of the fixed implant reconstruction and can be either supportive or compromising depending on the abutment material. As an example, different configurations of internal connections increase the resistance and stability at metal abutments. Yet, at ceramic abutments, the appropriate configuration of the internal connection, that is, the design and dimensions, is crucial for good outcomes. At some configurations, fractures of the internal connection part were reported. Hence, decisions have also to be taken at the level of the implant-abutment connection, and clinicians need to be aware of the outcomes of the current restorative options at the different implant-abutment connections.

With these different options and decision-making criteria in mind, groups of experts were given the tasks to analyze the current state of evidence in fixed implant prosthodontics with specific focus on the digital and conventional workflows, on the outcomes of the all-ceramic fixed implant reconstructions and on the influence of the type of implant-abutment connection on the clinical survival and complication rates. The following reviews were the basis of the present consensus report:

Mühlemann S, Kraus RD, Hämmerle CHF, Thoma DS. Is the use of digital technologies for the fabrication of implant supported reconstructions more time efficient and/or more effective than conventional techniques? A systematic review (Mühlemann, Kraus, Hämmerle & Thoma, 2018).

Rabel K, Spies BC, Pieralli S, Vach K, Kohal RJ. The clinical performance of all-ceramic implant-supported single crowns: A systematic review and meta-analysis. (Rabel, Spies, Pieralli, Vach & Kohal, 2018).

Pieralli S, Kohal RJ, Rabel K, Stein-Lausnitz V M, Vach K, Spies BC. Clinical outcomes of partial and full-arch all-ceramic implant-supported fixed dental prostheses. A systematic review and meta-analysis (Pieralli et al., 2018).

Pjetursson BE, Zarauz C, Strasding M, Sailer I, Zwahlen M, Zembic A. A systematic review of the influence of the implant-abutment connection on the clinical outcomes of ceramic and metallic implant abutments supporting fixed implant reconstructions (Pjetursson et al., 2018).

Based on the outcomes of these reviews, the topics were all discussed within the group, and minor amendments to the reviews were performed where needed. The group developed the consensus statements of the reviews, and formulated clinical recommendations and implications for future research.

These consensus statements and recommendations were then presented to the plenum, where they were thoroughly discussed, modified if needed, and, finally, approved.

Many of the present statements may not be applicable in a number of years due to the fast evolution of technology and materials, hence, updates of the present reviews may become necessary in the future.

## 2 | DIGITAL WORKFLOWS AND COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING (CAD/CAM) PROCEDURES VS. CONVENTIONAL PROCEDURES AND WORKFLOWS FOR THE FABRICATION OF FIXED IMPLANT RECONSTRUCTIONS

The aim of this review was to evaluate the current evidence of clinical studies evaluating the efficiency and/or the effectiveness of the digital workflows including CAD/CAM technology as compared to conventional workflows for the fabrication of implant abutments and reconstructions. The outcome measures for *efficiency* were time and costs needed for the respective procedures, and the outcome measure for *effectiveness* was the number of reconstructions in need of chairside adjustments and/or remakes. The review aimed to reply on the focused question, whether or not CAD/CAM fabrication of implant abutments and implant-supported reconstructions was more efficient and/or more effective than the conventional fabrication method.

### 2.1 | Major findings from the review

Owing to the huge heterogeneity of the fabrication workflows, the analysis of the published research did not provide sufficient information to answer the focused question of the review. Furthermore, the existing information was limited to posterior single-implant crowns and full-arch reconstructions in limited number of patients. Moreover, the degree of bias in the study methodology was not clear.

### 2.2 | Consensus statements

In the few studies (only 3), that compared the time needed for the intraoral optical impressions to the time needed for conventional impressions, the optical impression procedures were more time efficient than the conventional impressions. This rather weakly supported statement is, furthermore, limited to the tested optical impression systems.

The fastest laboratory fabrication procedure included a model-free fabrication of the reconstruction, using prefabricated abutments and applying monolithic design of the reconstructions. This statement again was weakly supported, as only three studies delivered the needed details, and these studies focused solely on posterior single-implant crowns.

### 2.3 | Clinical recommendations

Although the present review demonstrated some advantages for digital procedures, time efficiency may depend on several not yet evaluated factors, such as different systems, operators, dental technicians, and workflows.

Therefore, no clinical recommendation can be made at present.

### 2.4 | Implications for future research

Further clinical studies on time efficiency should include an exact description of the digital technologies as well as in which work step the technologies are applied. More clinical studies including more patients evaluating more implant systems, digital devices, and operators are needed to be able to provide definitive recommendations to the clinicians.

The studies should report in detail on

- patient selection criteria
- operator-related factors (like experience)
- methods for calibration
- patient-related factors
- clinical outcome parameters such as precision and esthetics

Future studies should specifically address the following open questions:

- Which of the parameters besides time, such as, for example, costs, waste of material, and/or investment in equipment, influence the efficiency of the digital and conventional workflows? To which degree do the factors have an influence?
- To which extent does the dental laboratory waiting time (time for milling, firing, equipment maintenance, transfer time) at the digital workflows exhibit an influence on the time for production of the reconstruction? A clear distinction should be made between centralized and in-laboratory processes.

Clinical crossover designs are recommended for this research area.

## 3 | THE CLINICAL PERFORMANCE OF ALL-CERAMIC IMPLANT-SUPPORTED SINGLE-UNIT AND MULTIPLE-UNIT FIXED IMPLANT RECONSTRUCTIONS

### 3.1 | Single crowns (SCs)

The first review of this topic evaluated the outcomes of all-ceramic single-implant crowns. The focused question of the review was "What are the survival as well as the complication rates of implant-supported all-ceramic SCs after a mean observation period of at least 1 year?"

The investigations included in the meta-analysis of the survival reported on single crowns made of veneered (21 studies) and monolithic (one study) high-strength oxide ceramics, veneered (four studies) and monolithic (eight studies) glass-based ceramics (lithium disilicate, feldspar, Empress 1) as well as resin-based reconstructions (one study). The remainder of the studies reported on pooled data (glass-based ceramics and high-strength ceramics) or did not mention whether the crowns were monolithic or veneered.

### 3.1.1 | Major findings from the review

All-ceramic implant SCs, in general, exhibit very good clinical outcomes. The overall survival rates of the all-ceramic SCs amounted to 93.0% after 5 years and 94.4% after 10 years in this review. Corresponding values for the survival estimates for implants of were 95.3% after 5 years and 96.2% after 10 years. The mean follow-up for the included studies was 4.6 years.

The 5-year SC survival estimates for the different all-ceramic material systems were the highest for the veneered oxide ceramics alumina and zirconia with 96.8% and 91.6%, respectively, followed by the monolithic lithium disilicate implant-supported SCs with an estimated 5-year survival rate of 91%. The lowest survival estimates were calculated for resin-based hybrid ceramics (67.0%). Framework fractures are a seldom complication, and the estimated 5-year rate for framework fractures was 1.9%. Resin-based hybrid ceramic crowns appear to be more prone to fracture, however. In the present review, the resin-based hybrid ceramic crowns exhibited significantly more core fractures than veneered alumina and zirconia.

The overall estimated complication rate for chipping of the veneering ceramic was 9% after 5 years. Chipping of the veneering ceramic occurred most frequently at veneered zirconia crowns (11.8%) and least at veneered alumina crowns (1.8%). Veneered glass-ceramic crowns (leucite-, lithium disilicate-reinforced) had low chipping rates as well (3.5%), whereas, interestingly, the monolithic lithium disilicate crowns exhibited 6% chipping of the ceramic. Chipping of the ceramic was not reported for resin-based hybrid ceramics.

Screw loosening was another predominant technical problem and occurred at an estimated 3.6% at 5 years. The material selection had no influence on the retention loss.

### 3.1.2 | Consensus statements

All-ceramic implant-supported SCs comprising veneered alumina, zirconia, lithium disilicate- and leucite-reinforced frameworks, and monolithic lithium disilicate crowns—either cement or screw-retained—showed high survival rates both in anterior and posterior regions.

However, occasional failures and technical complications occurred, which have to be taken into account when informing the patients on the treatment with all-ceramic SCs.

No statement can be made for monolithic zirconia due to lack of longitudinal data.

Hybrid materials (resin-based) are in the investigational stage and cannot be recommended for routine clinical use.

### 3.1.3 | Clinical recommendations

Both veneered and monolithic all-ceramic SC types can be considered as valid treatment options in anterior and posterior positions. However, it has to be understood that an appropriate manufacturing and handling of ceramic is crucial for the long-term outcomes.

Resin-based hybrid materials cannot be recommended for the use at implant-supported SCs at present.

### 3.1.4 | Limitations of the review

Vast amounts of material combinations of framework materials and veneering materials are available. However, the review was characterized by pooling of data of different types of ceramics reconstructions for statistical analyses. Information on monolithic materials is scarce.

Very limited information was found on monolithic zirconia with a follow-up time of at least 1 year.

Most of the observational studies found during the literature search for the present review were of moderate methodological quality.

## 3.2 | Partial and full-arch all-ceramic implant-supported fixed dental prostheses

The second review focussed on the outcomes of all-ceramic partial and full-arch fixed dental prostheses (FDPs). Analogous to the previous review, the focused question of the review was "What are the survival as well as the complication rates of implant-supported all-ceramic multiple-unit FDPs after a mean observation period of at least 1 year?"

The review mostly comprised veneered frameworks made of zirconia (528), and the remaining reconstructions (12) were made of zirconia toughened alumina. Veneering was performed by hand-layering. No studies on monolithic zirconia FDPs could be included. Partial reconstructions were entirely located in posterior regions and cement retained, whereas full-arch reconstructions were screw-retained. All except two studies pooled the outcome data from the mandible and maxilla.

### 3.2.1 | Major findings from the review

The 5-year survival estimates of zirconia-based partial (P) and full-arch (FA) FDPs were 98.3% and 97.7%, respectively. Corresponding values for the supporting implants were 98.5% for the P-FDPs and 99.4% for the FA-FDPs.

Chipping of the veneering ceramic was frequently observed at the reconstruction level (P: 22.8%, FA: 34.8%). Other technical complications such as framework fractures (four of 273 FA-FDPs), screw loosening (one FA-FDP), and de-cementation (11 of 267 P-FDPs) were occasionally observed.

Evaluated variables (study design, setting, veneering material, retention mode, cement, and location) did not significantly affect the outcomes (implant/reconstruction survival and chipping).

### 3.2.2 | Consensus statements

Implant-supported multiple-unit FDPs with a veneered zirconia framework exhibit high survival rates in terms of reconstructions and supporting implants. A high chipping rate of the veneered zirconia FDPs, however, was observed. The clinical relevance of the chippings is unknown, but this may present a questionable prognosis for the reconstructions.

### 3.2.3 | Clinical recommendations

Clinicians and laboratory technicians should be aware of the high incidence of chipping of the veneering ceramic at the zirconia-ceramic FDPs. This technical problem needs to be considered in treatment planning.

Clinical recommendations on alternative all-ceramic systems (e.g., monolithic FDPs) cannot yet be made due to the lack of data.

### 3.2.4 | Limitations of the review

Considering the inclusion criteria of this systematic review, literature on all-ceramic multiple-unit implant-supported FDPs is scarce. Moreover, references are limited to veneered zirconia reconstructions. Furthermore, the studies were of moderate methodological quality. Available reporting guidelines (like the CONSORT and STROBE statements) were either not adhered to or not followed in an appropriate manner.

Most of the included studies did not use standardized evaluation criteria for the assessment of complications (e.g., USPHS or CDA criteria).

No information on monolithic FDP's was available.

## 3.3 | Implications for future research on all-ceramic single-unit and multiple-unit fixed implant reconstructions

Future studies should specifically address the following open questions:

- What are the outcomes of multiple-unit veneered all-ceramic fixed implant reconstructions?

The studies should report in detail on the materials used, on veneering procedures and on the respective dimensions and designs of the frameworks and veneering ceramics.

- What are the outcomes of monolithic single- and multiple-unit zirconia fixed implant single- and multiple-unit reconstructions?

The studies should report in detail on the material composition (type of zirconia etc.) and whether or not local application of veneering ceramic was performed.

# 4 | SURVIVAL AND COMPLICATION RATES OF IMPLANT ABUTMENTS AND RECONSTRUCTIONS WITH INTERNAL AND EXTERNAL IMPLANT-ABUTMENT CONNECTIONS

This review evaluated the influence of the implant-abutment connection, that is, internal vs. external connections, on the outcomes of fixed implant reconstructions. The focused question was "In partially edentulous patients with fixed implant-supported reconstructions, do the type of the implant-abutment connection and the implant-abutment material influence the clinical outcomes?"

Fifty-eight percent of the abutments supporting SCs were metallic and 42% were all-ceramic (alumina/zirconia). Fifty-nine percent had internal implant-abutment connections and 41% external connections. Eighty-four percent of the SCs were cemented and only 16% were screw-retained.

Of the abutments supporting FDPs, 97% were metallic, 3% zirconia, 48% had internal implant-abutment connections, and 52% had external connections. Fifty-nine percent of the FDPs were cemented and 41% screw-retained.

## 4.1 | Major findings from the review

Meta-analysis of the included studies indicated an estimated 5-year survival rate of 97.6% for SCs and 97.0% for FDPs supported by implants with internal implant-abutment connections. The figures for implants with external implant-abutment connections were 95.7% for SCs and 95.8% for FDPs, respectively.

A 5-year abutment failure rate of 2.8% was reported for abutments with internal connections supporting FDPs. The corresponding value for SCs was 2.3%. The failure rate for abutments supporting FDPs with external connection was 0.7% and 1.3% for abutments with external connection supporting SCs. The differences between the two types of connections with respect to 5-year survival rates of the reconstructions and the failure rates of the abutments did not reach statistical significance.

The total numbers of biological and technical complications were similar between the two connection types, and yet, external implant connections were associated more often with occlusal and abutment screw loosening.

There was no significant difference in survival rates between metallic and ceramic abutments, but ceramic abutments fractured more frequently. This applied to both internally and externally connected ceramic abutments.

When comparing the survival rates of ceramic and metallic abutments supporting SCs in posterior regions, no significant differences were found in 5-year abutment survival rates (97.9% for zirconia abutments, 99.7% for metallic abutments). However, it must be kept in mind that there is still limited evidence on ceramic abutments in posterior areas (three studies with 100 internally/externally connected ceramic abutments in posterior regions).

In anterior regions, the respective comparison also displayed no differences between the 5-year abutment survival rates (97.5% for zirconia abutments, 97.4% for metallic abutments).

Likewise, the retention mode (cemented or screw-retained) of the reconstructions did not influence survival rates of abutments and reconstructions. However, abutment and occlusal screw loosening were significantly more frequent for the screw-retained reconstructions.

### 4.2 | Consensus statements and clinical recommendations

For implant-supported SCs, both metal and ceramic abutments with internal and external connections can be recommended according to the current literature.

For implant-supported FDPs, metal abutments with internal and external connection can be recommended. Owing to the lack of longitudinal data, zirconia abutments cannot be recommended as yet for implant-supported FDPs.

### 4.3 | Limitations of the review

The included studies often clustered data from patients with different observation periods instead of following patients for a well-defined time period. Furthermore, there is a lack of standardized approaches to report biological and technical complications. Finally, the methodological quality of the included studies was moderate.

### 4.4 | Implications for future research on implant-abutment connections

Future studies should address special issues such as internal vs. external implant-abutment connections, screw-retained vs. cemented restorations, materials used, including well-proven solutions as control with an adequate statistical power.

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From left to right, starting from the top: Riccardo Kraus, Guillem Esteve Pardo, Javier Amigó Bardají, Ralf Kohal, Klaus Gotfredsen, Bassam Hassan, Benedikt Spies, Ann Wennerberg, Irena Sailer, Mutlu Ozcan, Bjarni Pjetursson, Helena Francisco, Jan-Eirik Ellingsen, Niklaus Lang, Sven Muhlemann