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ORIGINAL ARTICLE

Implant-supported full-arch zirconia-based mandibular fixed dental prostheses. Eight-year results from a clinical pilot study

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Abstract

Objective. The purpose of this pilot study was to evaluate the long-term clinical performance of implant-supported full-arch zirconia-based fixed dental prostheses (FDPs). **Materials and methods.** Ten patients received full-arch zirconia-based (Cercon) mandibular FDPs supported by four implants (Astra Tech). Nine patients received 10-unit FDPs and one patient received a 9-unit FDP. The FDPs were cemented onto individually prepared titanium abutments and were evaluated at baseline and after 12, 24, 36 and 96 months. **Results.** Nine patients attended the 8-year follow-up. None of the restorations showed bulk fracture, all FDPs were in use. Fractures of the veneering porcelain were, however, observed in eight patients. A total of 36 out of 89 units (40%) showed such fractures. Patient satisfaction was excellent despite the veneering material fractures. **Conclusion.** Results from this 8-year pilot study suggest that implant-supported full-arch zirconia-based FDPs can be an acceptable treatment alternative.

Key Words: *yttria-stabilized tetragonal zirconia, veneers dental, prosthesis failure analysis*

Introduction

Fixed dental restorations can be made from many different materials. There is extensive evidence of the excellent long-term results of conventional high-noble-alloy-based metal ceramic restorations (MCR) [1–3], but, as some studies have reported on potential adverse reactions against gold [4], attention has been focused on even more biocompatible materials as alternatives.

In recent years fixed dental restorations based on yttria-stabilized tetragonal zirconia polycrystals (Y-TZP) have become popular thanks to excellent biocompatibility and good aesthetics. An increasing amount of studies on zirconia-based restorations have shown acceptable survival rates, similar to conventional MCR restorations [5]. The risk of complete failure is minimal for zirconia-based restorations. However, almost all studies report fractures of the veneering material and implant-supported restorations have been especially prone to such complications [5,6].

Very few veneering material fractures have led to the removal of restorations, many patients have been unaware of them at follow-up and the importance of

the veneering material fractures should therefore not be over-emphasized. They are, however, important to discuss since they often lead to some need for adjustment. The frequency of veneering material fractures varies considerably and no studies have reported long-term results. The aim of this study is therefore to provide long-term results from a pilot study on implant-supported zirconia-based fixed dental prostheses.

Materials and methods

Patient selection

Patients referred to the Department of Prosthetic Dentistry at Malmö University in need of prosthetic full-arch rehabilitation in the lower jaw were selected consecutively and offered participation in the present study. Exclusion criteria were medical or psychological conditions preventing implant placement, insufficient bone dimensions, unsatisfactory oral hygiene and bruxism. Ten patients (six women and four men between the ages of 52–76) were included in this pilot trial. The patients were edentulous in the lower jaw. In the maxilla, five patients wore full-arch implant-

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Table I. Marginal integrity according to the modified CDA-protocol.

| Score | Criteria |
|----------------------------|---|
| Romeo (excellent) | No visible evidence of a crevice along margin into which the probe can penetrate |
| Sierra (acceptable) | Detectable slight marginal discrepancy; repair is unnecessary |
| Tango (retrievable) | Faulty margins that cannot be properly repaired Retained excess cement |
| Victor (not acceptable) | Mobile restoration Fractured restoration Fractured secondary implant component Fractured implant |

supported MCR FDPs, four patients wore full-arch tooth-supported MCR FDPs, and one patient was partially dentate and wore a removable partial denture. The patients were informed about the protocol of the study and the risks with and alternatives to the proposed treatment and all gave their informed consent. An extended warranty for the restorations was offered in the case of failure. Ethical approval for the study was obtained from the Regional Ethical Review Board in Lund, Sweden (ref no: LU 571-02).

Procedures

Four dental implants (Fixture MicroThread ST 4.0, Astra Tech, Göteborg, Sweden) were placed in the lower jaw in a one-stage surgical procedure according to the manufacturer's protocol. The healing time before prosthetic treatment was started was 4 weeks. During the period until prosthetic treatment was completed, with the exception of the 1-week period from surgery until suture removal, the patients wore mandibular dentures.

Full-arch impressions were made at the implant level with a polyether impression material (Impregum[®], 3M ESPE, Sollentuna, Sweden) in disposable trays (SOLO[®], DAVIS, North Hollywood, CA). Impressions of the opposite jaw were made using rigid standard stainless steel trays with alginate (Blueprint Cremix, Dentsply, York, PA). Inter-occlusal registrations were made with the aid of wax rims manufactured by the dental technician. A wax set-up with acrylic denture teeth was used to check vertical and horizontal registrations before starting the processing of the FDPs. Implant abutments (Profile BiAbutment ST, Astra Tech, Göteborg, Sweden) were prepared with a cervical shoulder depth of 1.2 mm and slightly rounded inner angles. The preparations allowed a minimum material thickness of 1.7 mm occlusally and 1.5 mm buccally, approxiamally and lingually. The angle of convergence was aimed at 15°. After preparation the abutments were sandblasted with aluminium oxide powder (110 µ at 2 bars pressure).

The laboratory procedures were performed according to the manufacturer's (Cercon[®], DeguDent, Hanau, Germany) instructions at an authorised laboratory. The frameworks were inspected clinically and examined radiographically from the occlusal and buccal aspects to detect any possible flaws. After inspection, the frameworks were veneered with porcelain recommended by the manufacturer (Cercon ceram S, DeguDent, Hanau, Germany) and fired accordingly in calibrated furnaces.

To avoid creating micro-cracks and flaws in the material in connection with removal, no temporary cementation was performed. The completed restorations were fitted, adjusted and cemented permanently with Panavia F 2.0 (Kuraray, Tokyo, Japan) in one sitting. The patients were thereafter scheduled for final check-ups 1–2 weeks after cementation. Follow-up examinations were performed by two calibrated dentists, others than the operator responsible for the treatment, at baseline and 12, 24, 36 and 96 months.

Evaluation/follow-up

The marginal integrity and surface were rated as excellent, acceptable, retrievable or not acceptable according to a slightly modified California Dental Association (CDA) quality assessment system [7]. The modifications consisted of an adaptation of the CDA system to implant-supported restorations as well as additional information on veneering material fractures (Tables I and II).

Restorations remaining *in situ* without any complications, i.e. only Romeo ratings according to the assessment system, were defined as success. Survival was defined as the restoration remaining *in situ* with one or more complications (Sierra ratings). Failure was defined as restorations in need of replacement or having been removed (Victor ratings). Restorations showing veneering material fractures (Tango rating) were considered surviving when the restorations could be adjusted, i.e. polished, or repaired. Restorations showing extensive veneering material fractures

Table II. Surface according to the modified CDA-protocol.

| Score | Criteria |
|----------------------------|--|
| Romeo (excellent) | The surface of the restoration is smooth No irritation of adjacent tissue |
| Sierra (acceptable) | Surface of restoration is slightly rough or pitted; can be polished but is not necessary |
| Tango (retrievable) | Irregular surface and/or chip-off fractures with no change in functional anatomy. Can be polished/repaired |
| Victor (not acceptable) | Fractures that cannot be corrected by polishing. Anatomical form functionally insufficient, e.g. loss of occlusal and/or approximal contacts |

Table III. Placement of the restorations and location of veneering material fractures at the 96-month follow-up.

| | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|----|----|
| 1 | | | | 45▶ | 44■ | 43X | 42 | 41X | 31 | 32 | 33● | 34▶ | | | | |
| 2 | | | | 45 | 44 | 43 | 42 | 41 | 31▶ | 32 | 33 | 34 | 35 | | | |
| 3 | | | | 45 | 44● | 43 | 42 | 41▶ | 31 | 32X | 33 | 34■ | 35● | | | |
| 4 | | | | 45 | 44● | 43 | 42 | 41 | 31 | 32 | 33X | 34● | 35● | | | |
| 5* | | | | | | | | | | | | | | | | |
| 6 | | | | 45● | 44 | 43 | 42 | 41 | 31 | 32 | 33● | 34X | 35● | | | |
| 7 | | | | 45● | 44● | 43● | 42● | 41▶ | 31▶ | 32X | 33▶ | 34▶ | 35▶ | | | |
| 8 | | | | 45 | 44 | 43 | 42■ | 41X | 31▶ | 32● | 33X | 34 | 35 | | | |
| 9 | | | | 45 | 44 | 43 | 42 | 41 | 31▶ | 32 | 33 | 34 | 35 | | | |
| 10 | | | | 45 | 44 | 43 | 42 | 41 | 31 | 32 | 33 | 34 | 35 | | | |

* FDP nr 5 excluded, patient deceased.

Italic, Abutment (numbered according to the FDI 2-digit tooth numbering system).

Underlined, Pontic.

▶, Chip-off fracture revealed at the 12 month follow-up; ■, Chip-off fracture revealed at the 24-month follow-up; ●, Chip-off fracture revealed at the 36-month follow-up; X, Chip-off fracture revealed at the 96-month follow-up.

affecting function or aesthetics to such a degree that adjustment or repair was not possible (Victor rating) were defined as failure.

In addition to the clinical examination, the patients were asked to fill out a questionnaire rating their satisfaction with their treatment from 0 ('not satisfied at all') to 10 ('completely satisfied') as well as answering a question of whether or not they would recommend this treatment to someone else.

Results

Ten patients received implant-supported zirconia-based FDPs; nine patients received 10-unit FDPs and one patient received a 9-unit FDP. One of the patients, with a 10-unit FDP, passed away, all other patients attended the 8-year follow-up.

All FDPs were still in use at follow-up. No bulk fractures were noted and none of the restorations were in need of repair or replacement—indicating a 100% survival rate. Fractures of the veneering porcelain were, however, observed in eight of the nine patients. A total of 36 of the 89 units (40%) showed such fractures. The fractures occurred on different surfaces, none of the fractures impaired functions or aesthetics. All fractures could be polished and were rated Tango, i.e. survival.

The number of veneering material fractures increased from zero at baseline to 14 units (14%) in seven patients at 12 months, 18 units (18%) in seven patients at 24 months and 34 units (34%) in nine patients at 36 months (Table III).

Marginal integrity was rated Romeo (excellent) at 23 abutments (64%) and Sierra (acceptable) at 13 abutments (36%). Corresponding results from the 36-month follow-up were 70% Romeo and 30% Sierra, 77.5% Romeo and 22.5% Sierra ratings

at the 12-month follow-up and 82.5% Romeo and 17.5% Sierra at baseline evaluation. No margins were rated Tango or Victor.

The patients were fully satisfied with the treatment. Seven of the patients rated their satisfaction with their restoration as 10/10, one as 9/10 and one as 8/10. All patients answered that they would recommend this treatment.

Discussion

Reports on zirconia-based restorations have shown that the overall survival of these restorations is similar to that of high-noble-alloy-based metal ceramic restorations, the gold standard [5]. The risk of complete failure is minor for tooth-supported restorations and has not been reported for implant-supported restorations [5,6]. The results from the present pilot study are in accordance with this as no bulk fractures were noted and all restorations were still in function after 8 years.

The higher frequency and risk of veneer failure for the zirconia-based FDPs compared with MCR FDPs has been a concern though. Most studies on tooth-supported restorations and all studies on implant-supported restorations report veneering material fractures [5,6]. As implant integration into bone provides a more solid support compared to natural teeth [8,9], they have been suggested as suitable abutments for all-ceramic FDPs in an *in-vitro* study [10]. The veneering porcelain, however, appears to be subjected to loads that exceed its load-bearing capacity when the restoration is supported by implants, resulting more frequently in chip-off fractures [11,12]. Thus, the positive results from the implant support seem to be outweighed by the negative effects on the veneering porcelain.

The veneering material fractures in the present study did not affect function or aesthetics, they could be adjusted by polishing and remain *in situ* and the patients were very satisfied with the treatment. Patients enrolled in a research project are carefully monitored and the extra attention may influence their perception of treatment in a positive way. When performing the evaluation of patient satisfaction, staff not involved in the treatment and research project handed out and collected the questionnaires as well as compiled the results. It was made clear to the patients that their answers were anonymous and would not affect their treatment. Even so, it cannot be ruled out that the process has not influenced their responses. However, looking at the fact that many of the patients were unaware of the veneering material fractures at follow-up and that none have asked to have their restorations replaced we can conclude that the importance of veneering material fractures should not be over-emphasized.

Despite this, it is important to discuss veneering material fractures. A fracture creates a rough surface, and sometimes sharp edges that lead to some need for adjustment. When occurring in the anterior areas, it may also affect aesthetics and a large veneering material fracture can also impair function, e.g. occlusion or approximal contacts, in such a way that replacement becomes necessary.

From the perspective of materials science the veneering material fractures are also interesting to discuss. Many different factors of possible influence have been suggested [13]. Factors such as type of veneering material and technique, framework design, bond between core and veneer, thickness and cooling rate after firing have been mentioned.

Studies comparing porcelain and glass ceramic veneering materials with differences in composition and strength have not found any effect on fracture mode [14,15]. The technique of sintering veneering caps onto the core has, however, shown promising results compared with conventional veneering, highlighting the importance of the aspect of controlling material handling [16]. Other studies comparing press-on veneering to manual layering have sometimes shown improved results with the press-on technique [17] and sometimes not [18,19]. In summary, the type of veneering material and technique used does not fully explain the veneering material fractures.

Instead there is increasing evidence that the design of the core/framework supporting the veneering material is crucial to avoid fractures. If the veneering material is unsupported the risk of fracture is significantly increased [15,20,21]. This is associated with another important factor—the thickness of the veneering material. With increasing thickness of veneering material on frameworks with low thermal diffusivity such as zirconia, high residual stresses are generated making fractures more likely compared to

thin layers [22]. The uncontrolled stresses may increase further if the firing process and subsequent cooling is not properly performed [22].

As seen from the discussion above, many factors have been suggested to influence the risk of veneering material fractures. Most probably, these factors should not be considered as independent variables but rather interacting [13]. The present study was initiated almost 10 years ago and, even though the restorations were manufactured according to recommendations at that time, it is possible that the success rates of restorations produced today might be different because of the improved understanding of zirconia as a dental restorative material that has become available in recent years. When analysing reviews on tooth-supported zirconia-based FDPs it is clear that the frequencies of veneering material fractures are less in more recently produced studies than in those publications initiated early [5,23].

Aspects of the method used

Only 10 patients were included in the present study, which has to be considered a pilot study. This limits the conclusions drawn. Further studies, including a larger number of patients and preferably with a control group, would be valuable. The patients in the present study were all treated by specialists at a clinic for prosthetic dentistry. This may limit the applicability of the treatment outcome compared to other groups of treatment providers [24].

Conclusion

Results from this pilot study suggest that implant-supported full-arch zirconia-based FDPs can be an acceptable treatment alternative. The survival rate of the restorations as well as patient satisfaction is excellent, despite the occurrence of veneering material fractures. Further studies, including a larger number of patients, would, however, be valuable.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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