A 3-year retrospective and clinical follow-up study of zirconia single crowns performed in a private practice

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1. Introduction

Metal crowns were for long the most common restorations for decayed, heavily repaired, fractured or worn teeth. During the last few decades, metal–ceramic crowns have been the restoration of choice because of their esthetic quality and high success rate.1,2 Demands for more esthetic materials and metal-free restorations have led to increased interest in the development of dental ceramics.3–5 The original porcelain jacket crown, fabricated of a feldspar ceramic, met high esthetic demands, but because of low strength it could be used only on anterior teeth.6 New ceramic materials have been introduced and proposed for use in the posterior region, but early clinical results and laboratory analyses indicated that they were safe only for anterior teeth since they exhibited higher failure rates than metal–ceramic crowns on posterior teeth.7,8

Oxide ceramics based systems such as crystalline alumina and zirconia are superior to feldspathic ceramics with respect to mechanical properties, which have made them a favourable
choice for metal-free restorations also in the posterior region. The mechanical properties of zirconia (zirconium dioxide, ZrO₂) are the highest ever reported for any dental ceramic, which naturally has generated considerable interest. Since it is also characterized by low thermal conductivity, low corrosion potential, good radiographic contrast, and good biologic compatibility it is considered a most promising dental material. Zirconia has been used clinically during the last few years but there are only few studies reporting the long-term results. Several studies of relatively few patients have reported promising results with zirconia fixed dental prostheses (FDP) with up to 100% survival but varying complication rates during 1–3 years in function. In a study of 3–5-unit zirconia FDPs only 1/57 frameworks fractured but other complications reduced the success rate to 74% up to 5 years. In contrast, a prospective study of 19 3-unit zirconia FDPs reported that all of them were intact at the 5-year examination.

Surprisingly, the zirconia restorations most often described in the literature are FDPs rather than single crowns, although crowns constitute the most common fixed prosthodontic treatment. Some short-term clinical reports and two systematic studies including small numbers of zirconia crowns have been published up to now. The rapidly growing use of zirconia in dentistry warrants more clinical research on crowns made with this ceramic material.

The aim of this retrospective and clinical follow-up study was to evaluate the 3-year clinical outcome of a large number of zirconia-based crowns, performed in a general dental practice.

2. Methods

2.1. Study design

This is a retrospective evaluation of patient records and a clinical follow-up examination of patients treated with zirconia crowns in a general dental private practice in Sweden. The patients belonged to the ordinary clientele of the clinic and were treated by one dentist with experience of prosthodontics for more than 30 years and with a long interest in all-ceramic restorations. From October 2004, zirconia (NobelProcera Crown Zirconia, Nobel Biocare AB, Stockholm, Sweden) has been the only material used for single crowns in the clinic. Registration of the records of all patients (n = 169) who had received zirconia crowns (n = 216) during the follow-up period October 2004 to November 2005 was performed from August 2008 to January 2009 by the authors. There was no information on eight patients (5%) with 12 crowns (6%) because they did not come back to the clinic after the insertion of the crowns. This study is thus based on data from 161 patients and 204 crowns. Of the 161 patients, 56% were women. The mean age was 56.0 (SD 11.2) years with a range from 25 to 85 years at the time of crown cementation.

On three full-day visits at the clinic during these months, 20 patients had been scheduled for their 3-year recall appointment as they had fulfilled the 3-year follow-up period that certain month. Two of them could not come to the clinic during the allotted days but the remaining 18 patients with 25 crowns were examined clinically by two of the authors.

Table 1 - Distribution of 216 zirconia crowns by region.

<table>
<thead>
<tr>
<th>Region</th>
<th>Maxilla</th>
<th>Mandible</th>
<th>Total crowns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incisor</td>
<td>31</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td>Canine</td>
<td>8</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Premolar</td>
<td>44</td>
<td>27</td>
<td>71</td>
</tr>
<tr>
<td>Molar</td>
<td>36</td>
<td>61</td>
<td>97</td>
</tr>
<tr>
<td>Total</td>
<td>119</td>
<td>98</td>
<td>216</td>
</tr>
</tbody>
</table>

The distribution of crowns by tooth position is presented in Table 1.

2.2. Prosthodontic procedures

The preparation of the teeth were performed with a deep chamfer and standardized as much as possible in accordance with the manufacturer’s guidelines (Nobel Biocare AB, Sweden). A polyether (Impregum Penta Soft, 3 M ESPE AG, Seefeld, Germany) was used for the impressions in a prefabricated tray (Triple Tray, Premier Dental Products, Plymouth Meeting, USA). Provisional crowns were cemented with a temporary zinc oxide eugenol (ZOE) cement, Nobetec (Nordiska Dental AB, Angelholm Sweden). Zirconia crown technique is described elsewhere. Briefly, the technique to fabricate the crowns involves that the plaster model of the prepared tooth is scanned and the zirconia core is designed using a computer-aided design (CAD). A computer-aided manufacturing (CAM) process of the crown is based on the digital information received and includes milling in as pressed zirconia. The zirconia copings are heated to 400 °C for binder burn-out and finally sintered at 1500 °C. The CAD technique was used by the laboratory to design the zirconia cores with an anatomic form, with a minimum thickness of 0.5 mm to ensure the right thickness of the veneers according to the manufacturer (Fig. 1). Feldspar porcelain, Vita Lumin (Vita Zahnfabrik, Bad Sackingen, Germany) or NobelRondo Zirconia (Nobel Biocare AB, Sweden) was fused to the cores by the laboratory. The veneering thickness layer was between 1.0 and 2.0 mm. The same dental laboratory (Expodent AB,
Malmö, Sweden) produced all the crowns and one company manufactured all the zirconia cores (NobelProcera™ Crown Zirconia, Nobel Biocare AB).

The abutment teeth were cleaned with ultrasonic and 70% alcohol (Spiritus Dilutus, Kemetyl AB, Haninge Sweden) before cementation. Zinc phosphate cement (Phosacem, Ivoclar Vivadent, Solna, Sweden) was used for cementation of the first 16 crowns and self-adhesive modified composite resin (Rely X Unicem, 3 M ESPE AG, Seefeld, Germany) was used for the other 200 crowns. No crowns were provisionally cemented before definitive cementation.

Out of 60 root canal treated teeth, 58 received a post and core. Three of these were cast gold-alloy post and core, and the remaining 55 prefabricated post (LIGHT-POST™, R.T.D, Saint Egreve, France). The posts were cemented with composite resin (Rely X Unicem, 3 M ESPE AG) and a core was built up with a composite material (Build-It™, Pentron LLC, Wallingford, USA). Two teeth were restored with composite without a post before fabrication of the crown.

2.3. Registrations and clinical examination

The patients were scheduled for check-ups after at one, two and three years, and the patients were asked to contact the clinic whenever they had problems with their crowns or abutment teeth.

Data was collected from the patient records regarding the following parameters: sex, age at crown delivery, number of crowns cemented, tooth position (Table 1), veneering material, cement, occluding teeth in the opposite jaw, endodontic treatment before delivery, post material, loss of vitality, secondary caries and prosthodontic complications such as loss of retention and fractures. The treatment with Zirconia crowns was considered a failure when the abutment tooth was extracted or a remake of crown was performed because of the lost retention, not polishable veneer fracture or persistent pain.

The following additional data were collected in the clinically examined patients: periodontal conditions (according to the CPITN22), periapical conditions (checking radiographs pre- and post-crown delivery), tooth mobility (classified: (1) ≤0.2 mm in horizontal direction; (2) 0.2–1 mm horizontally; (3) >1 mm horizontally; (4) mobility in vertical direction). The crowns were examined in accordance with the Californian Dental Association (CDA) system for quality evaluation for dental care.23 The patients were interviewed regarding their satisfaction with their crowns using a visual analogue scale (VAS) of 100 mm with the endpoints extremely dissatisfied (0) and extremely satisfied (100).

3. Results

3.1. Follow-up

During the inclusion period 216 crowns (Table 1) had been inserted in 169 patients. Most of the crowns (n = 168; 78%) were placed in the premolar or molar area (Fig. 2). Among the 169 patients who had received zirconia crowns ≥3 years before the registration of the records, 131 (78%) had been examined at the 3-year follow-up. The reason for losses to follow-up of patients is presented in Table 2. Eight patients (5%) with 12 crowns (6%) were not examined after cementation and the basis of the present evaluation is thus 204 zirconia crowns in 161 patients. Lost to follow-up crowns and cumulative survival rate (CSR) is presented in Table 3.

3.2. Patient record registrations

In total 32 crowns/abutment teeth (16%) experienced some type of complications. When easily manageable complications were excluded, such as temporary pain after cementation, excess of cement detected at next check-up, loosened crowns that easily could be re-cemented, the complication rate was 9%. Extraction of the abutment tooth, occurred for 5 (2%) teeth (one because of root fracture, four because of endodontic and periodontal problems). All of the extracted teeth had undergone root canal treatment before crown fabrication. Nine vital abutment teeth (6%) needed endodontic treatment during the follow-up. All endodontic problems occurred in posterior teeth.
During the follow-up period no core material fractured but four veneer fractures were recorded. Twelve crowns (7%) lost retention of which eight could be re-cemented. All but one of the loosened crowns were placed in the posterior region. One of the loosened crowns had been endodontically treated after cementation. No caries on the abutment teeth was reported. Three patients reported tooth sensitivity after cementation of the crown, which however disappeared within a few months for two of them, whereas the third required remake of the crown. In total 12 restorations (6%; in 10 patients) were recorded as failures: abutment tooth was extracted (5), remake of crown due to lost retention (4), veneer fracture (2) and persistent pain (1). The life table analysis demonstrated low failure rate during the first 2 years but it increased during the third year. The cumulative survival rate (CSR) was 92.7 after 3 years (Table 3).

In all patients but one, the zirconia crowns occluded against teeth or fixed dental prostheses (Fig. 3).

### 3.3. Clinical evaluation of 18 patients and 25 crowns

According to the CDA criteria, surface and colour, anatomic form and margin integrity were rated favourably and the deviations from the range of excellent were explainable (Table 5). Only four out the 25 crowns exhibited complete gingival health and 17 showed bleeding and calculus. Four teeth had more than 4 mm deep pockets. Of the six crowns with slight colour mismatch, three had a composite filling after endodontic treatment and three had a small area with too thin layer of veneering porcelain exposing the core material (in two cases probably from the start, in one due to wear or grinding).

Table 5 – Quality assessment according to CDA23 (%) of 25 zirconia crowns at 3-year follow-up.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Satisfactory</th>
<th>Not acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface and colour</td>
<td>76</td>
<td>24*</td>
</tr>
<tr>
<td>Anatomic form</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Margin integrity</td>
<td>80</td>
<td>20*</td>
</tr>
</tbody>
</table>

* R = range of excellence; S = range of acceptability; T = replace or correct for prevention; V = replace statim.
* Six crowns with slight mismatch between shade in restoration.
  Three crowns with visible evidence of marginal discrepancy with no decay, two crowns had retained excess cement that was removed.

Patient satisfaction with the zirconia crowns was in general high (Table 6).

### 4. Discussion

Among non-metallic materials used for small fixed dental prostheses (FDPs) zirconia has demonstrated good results in short-term and up to 5-year follow-up studies. In contrast to several reports on zirconia FDPs there are only few systematic studies of the clinical performance of zirconia crowns. The present study found favourable 3-year results of such crowns performed in a general dental practice. The clinical quality of the crowns according to the CDA evaluation was all in the satisfactory range. Patient satisfaction with the crowns was high. No caries was detected and no adverse soft tissue reactions around the crowns were observed. However, the periodontal conditions according to CPITN indicated a need for improved oral hygiene and/or scaling in most patients. There was no ceramic core fracture...
and only four feldspar porcelain veneer fractures (2%), among the 204 zirconia crowns, of which the great majority (78%) was placed on premolars and molars. In the two only yet published controlled clinical studies of zirconia-based crowns, relatively low complication rates were found over a 2-year period.20,21 The authors of both these studies concluded that the investigsted all-ceramic crowns could sufficiently withstand functional load in the posterior zone. The present 3-year study corroborates these results.

In a review of complications in fixed prosthodontics, 22 studies of all-ceramic crowns were identified, none including zirconia restorations.24 The mean complication incidence was 8%. Crown fracture was the most common cause for failure, strongly related to the location of the restoration. The fracture rates for anterior, premolar and molar all-ceramic crowns were 3%, 7% and 21%, respectively. As there was no crown fracture in the present material it can be concluded that zirconia crowns behave differently from earlier all-ceramic restorations. The previous recommendation to avoid all-ceramic restorations on posterior teeth7 does not seem relevant for zirconia crowns according to the available short-term results. Longer observation periods are necessary to secure such a statement.

There were low rates of other complications, such as loss of retention, endodontic problems and root fracture, but they had most probably other causes than the ceramic material. The modern preparation technique for zirconia crowns does not prescribe deeper preparation than for metal–ceramic crowns since the core can be made only 0.5 mm thick. However, the relatively high rate of loss of retention could probably be related to tooth preparation or cement used. The total incidence of all complications was relatively high but if the simple complications were excluded, such as temporary pain after cementation, excess of cement detected at next check-up, loosened crowns that easily could be re-cemented, the complication rate was 9%. Similar complication rates have been reported for fixed prosthodontic restorations/crowns made of other materials.8,24 The mean complication incidence in a survey of all-ceramic studies before the zirconia era was 8%.24 In the present study the rates of loss of retention (6%) and endodontic problems (5%) were higher than the means in the earlier all-ceramic studies (2% and 1%, respectively). In a systematic review of all-ceramic and metal–ceramic crowns, not including any zirconia restorations,8 the 5-year survival rates were similar for the two types of crowns when used for anterior teeth but on average lower for the all-ceramic crowns when used for posterior teeth (93% compared with 96% for metal–ceramic crowns). In this study the 3-year CSR was 93%. In a 2-year prospective trial of zirconia-based (ZrSiO4) crowns the Kaplan–Meier prospective survival rate after 24 months was 90%.21 Because of the differences in study design, patient materials and outcome criteria, it is hardly meaningful to make further detailed comparisons of the results of different studies. It may be prudent to wait for findings after longer follow-up periods.

Higher failure rate for root filled compared to vital abutment teeth has been demonstrated in several studies of metal–ceramic crowns,1,2 findings, which concur with those in the present study. In the present material all endodontic problems and most (11/12) loosenings occurred in crowned teeth in the posterior region. One explanation might be that the molars and premolars had more severe loss of tooth substance than the anterior teeth before crown fabrication. Nevertheless, zirconia crowns appear to be able to withstand the functional loads also in the posterior region.

Several limitations of the study might be considered. The results represent only one private practice and are therefore not generalisable. However, it is a practice-based study, which is considered to offer the advantage of being conducted by a “real-world” clinician in a general dental practice.25 Due to practical reasons only 11% of the originally placed crowns were examined clinically, but that was in accordance with the design of the study: scrutiny of patient records of at least 200 zirconia crowns and a clinical examination of 20 patients after 3 years. The clinical examination (comprising 90% of the planned patient sample) verified the relevance of the registrations in the patient records and gave an impression of the quality of the crowns. The loss of patients in a longitudinal study is always a limitation. The loss in this study is of moderate size and has been taken into consideration by means of a life table analysis. The study would be of interest because of the relatively large number of zirconia crowns investigated in comparison with other studies published up to now.

5. Conclusions

The results of the present 3-year study suggest that zirconia crowns (NobelProceraTM) are a promising prosthodontic alternative also in the premolar and molar regions. However, to evaluate the long-term success further studies are necessary.

Conflicts of interest

The authors declare no conflicts of interest.

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REFERENCES


