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Monolithic zirconia crowns in the aesthetic zone in heavy grinders with severe tooth wear – An observational case-series

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ABSTRACT

Objectives: The aim of this study was to assess the clinical outcomes and patient satisfaction with monolithic zirconia crowns in patients with severe tooth wear (≥1/3 of the tooth crown) in the aesthetic zone.
Methods: The historical prospective study sample consisted of 13 patients previously treated with a total of 84 monolithic zirconia crowns. The patients had been treated in a private clinic in Bergen, Norway, in the period 2012 to 2014. All patients were men, aged 35–67 years (mean age 56.3 years) and had been in need of prosthetic rehabilitation because of severe tooth wear in the aesthetic zone. Technical complications as well as biologic findings were registered when the crowns had been in function one to three years (mean 20 months). The patients completed a self-administered questionnaire regarding satisfaction with aesthetic and function.
Results: No biological complications were registered in 79 of the crowns (94%), and technical complications were registered in only two patients. All patients were satisfied with the aesthetic and function of the monolithic zirconia crowns and would choose the same treatment modality if they were to be treated again.
Conclusions: Within the limitations of this study, we conclude that the rate of clinical complications was low and that the patients were satisfied with the aesthetic as well as the function of the monolithic zirconia crowns.
Clinical significance: Monolithic zirconia crowns may provide a valid treatment modality in the aesthetic zone in patients with severe tooth wear.

1. Introduction

Heavy grinders may wear down their teeth to such an extent that rehabilitation is indicated for aesthetical, functional and biological reasons. There are, however, no hard and fast rules for the treatment of worn teeth in heavy grinders [1]. Only in a respectful dialogue between the dentist and the patient can a treatment plan be established and fulfilled [2]. The purpose of the treatment is primarily to prevent further wear and furthermore to re-establish aesthetics and function with minimal biological cost. This can be challenging since aesthetics and strength of restorative materials have so far not been easily combined [3–5]. The most aesthetically and biologically minimal invasive materials, like feltspatic ceramics and composites, are also the weakest, whereas the strongest materials like metals have inferior aesthetics.

The most argued treatment indication for heavy grinders is to improve aesthetics, as they normally do not have problems chewing. The extensive grinding forces in these patients require a restorative material with adequate wear-and fracture resistant properties [1,6]. For this reason, metal-ceramic restorations have for many years been considered “the golden standard” in fixed prosthodontics in heavy grinders. However, the metal framework makes it difficult to mimic natural aesthetics and the veneering ceramic might chip off, exposing the metal core [7]. Alternative materials for dental rehabilitation with better aesthetics have to be comparable to metal-ceramics, particularly with regard to veneer chipping, core fracture, and marginal fit [8]. As the properties of all-ceramic restorations have improved during the last decades, there has been a trend towards using more metal-free restorations because of the superior aesthetics of all-ceramic restorations [9].

In a systematic review from 2007 the estimated 5-year survival rate for metal-ceramic and all-ceramic single crowns was reported to be almost equal; 95.6% vs 93.3% [7]. However, the 5-year chipping complication rates were higher for all-ceramic crowns than for metal-ceramic crowns; 5.7% vs 3.7%. Another systematic review from 2015 reported similar results regarding complication rates of metal-ceramic versus all-ceramic crowns and ceramic veneer chipping was reported as a common problem [3]. Thus it seems that even with significant improvements in material properties and excellent aesthetics, the performance of all-ceramic crowns still fails to match that of metal-ceramic crowns [4].

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The introduction of high strength oxide-ceramics as the core material improved the aesthetic properties compared to metal-ceramic crowns, but also these crowns show higher chipping rates than conventional metal-ceramics crowns [10]. A systematic review from 2010 reported excellent results regarding core fracture; less than 1% in the zirconia group and 0% in the metal-ceramic group after 3 years [8]. However, the rate of chipping was much higher for the bi-layered zirconia group than for the metal-ceramic group; 54% vs 34%. Common for all publications included in these reviews is that patients with parafunctions such as grinding are usually excluded from the study populations.

Chipping and fractures of veneering ceramic is thus a problem both on metal-ceramic and all-ceramic crowns. In recent years high-strength monolithic zirconia crowns with superficial glazing and staining have been tested in high-load bearing areas [5]. The monolithic zirconia crowns do not have a veneering ceramic, and are expected to have less chipping and fracture complications. On the other hand, the monochromic and opaque aesthetic properties of monolithic zirconia restorations make them aesthetically inferior to veneered restorations. The use in the aesthetic zone has thus been very limited. Monolithic zirconia might, however, be an acceptable treatment choice for heavy grinders. Most studies on clinical performance of single crowns exclude patients with bruxism and/or parafunctional habits because higher rates of mechanical complications such as chipping and fractures can be expected in this group of patients compared to non-grinders [6]. Hence, there is a lack of studies on the clinical outcomes of monolithic zirconia crowns in the aesthetic zone in patients with heavy grinding habits. Likewise, there is a lack of studies with patient reported outcomes regarding this treatment modality.

The aim of this study was to assess the clinical performance and the patient satisfaction with monolithic zirconia crowns in the aesthetic zone in heavy grinders with worn dentition.

Table 1
Teeth treated with zirconia crowns for each patient.

Patient number	1	2	3	4	5	6	7
Treated teeth	14–23	12–13, 44, 42–33	13–25	33–42	44–35	12–22	13–23

Patient number	8	9	10	11	12	13
Treated teeth	13–23	13–23	15, 12–23	13–23	12–22	13–23

2. Materials and methods

2.1. Sample

Patients with severe tooth wear, including at least 1/3 of the coronal tooth substances, in the aesthetic zone (incisors, canines and premolars) restored with fixed prosthodontics were included in this historical prospective study. The study included all patients with this specific tooth wear referred to one specialist in prosthodontics (HG) for rehabilitation (Fig. 1). The patients were referred for treatment after having been observed over a period of time by the referring dentist [11]. The study sample consisted of 13 patients with a total of 84 monolithic zirconia crowns (Table 1). The patients were informed of the study with an invitation to a clinical assessment and consented to participate by showing up to the appointment. All patients were men between 35 and 67 years of age (mean 56.3 years). All the patients in the study had an edge-to-edge bite prior to treatment. Their vertical dimensions were increased upon receiving crown therapy and occlusal relations were adjusted in to a normal horizontal overbite. The vertical dimension in the front was increased 1–2 mm in all patients, and all had complete occlusal contact at the control 1–3 years after treatment.

Fig. 1. A) Before treatment: Clinical photo of a typical patient with severe tooth wear in the aesthetic zone. B) After treatment: Clinical photo of monolithic zirconia crowns with a 3 years follow-up time.

The inclusion criteria were

- Severe tooth wear in the aesthetic zone.
- The patient preferred strength and durability of the restorations as compared to aesthetics.
- All teeth in need of treatment had been restored with monolithic zirconia single crowns (BruxZir®, Glidewell Laboratories, USA) and cemented with resin modified glass ionomer cement (Fuji plus®, GC Corporation Tokyo, Japan) (Fig. 1).
- The patients did not wear an occlusal night guard after treatment.

The treatment had been performed according to the general guidelines for the materials used. The yttria-stabilized zirconia material was soft-machined by CAD/CAM technique according to manufacturer's instructions. Dental technicians polished the outer surface. The restorations were assured to fit in occlusion and articulation movements before cementation and no adjustments were needed before or after cementation.

3. Methods

The patients were examined clinically one to three years (mean 20 months) after the crowns had been cemented. The clinical outcomes were registered for every tooth as biological findings, technical findings and complications. Two examiners were trained and calibrated prior to performing the clinical evaluations. The biological findings; plaque, bleeding on probing (BoP) and caries, were registered on a dichotomous scale as *yes* or *no*. Plaque was registered as *yes* if visible on the probe after one stride along the buccal gingival margin of the crown on the buccal/labial surface only. BoP was registered as *yes* if bleeding occurred after one single pocket depth measurement by probing (~25 g). Caries was registered as *yes* if diagnosed visually and by probing. Radiographic examination was not performed as all crowns margins were supragingival and easily accessed visually. Technical findings were registered using a modified California Dental Association scale (CDA-Scale) to evaluate Surface, Color, Anatomic form and Marginal integrity, and registered accordingly (Fig. 2).

Quality Evaluation Criteria According to the CDA

Operational explanation
1=R (Romeo) – Range of excellence
2=S (Sierra) – Satisfactory
3=T (Tango) – Unsatisfactory, future damage is likely to occur.
4=V (Victor) – Unsatisfactory, damage to patient is now occurring.

Colour
1- There is no mismatch in color or translucency between restorations and adjacent teeth.
2- Slight mismatch between shade of restoration and adjacent teeth, within normal range of tooth colour, shade and/or translucency.
3- Mismatch between restoration and adjacent teeth outside normal range of colour, shade and/or translucency.
4- Shade is in gross disharmony with adjacent teeth.

Surface
1- Surface of restoration is smooth, no irritation of adjacent tissue is occurring.
2- Surface is slightly rough, pitted; can be polished.
3- Surface is grossly irregular, deeply pitted or with irregular grooves, not related to anatomy and not subject to correction.
4- Surface is fractured, there are gross porosities in crown material, or surface is flaking.

Shape (Anatomic form)
1- Restoration contour is in functional harmony with adjacent teeth and soft tissues with good individual anatomic form.
2- Anatomic form is in acceptable harmony with adjacent teeth, can be slightly overcontured or undercontured.
3- Anatomic form is not in acceptable harmony with adjacent teeth. Grossly overcontured or undercontured. Occlusion is affected.
4- Anatomic form is in gross disharmony with adjacent teeth. Restoration causes unremitting pain in tooth or adjacent tissue, traumatic occlusion or gross underocclusion.

Margins
1- No visible or explorable crevice along the crown margin. No discoloration on margin between restoration and tooth structure.
2- Slightly visibly discrepancy and/or discoloration along the crown margin. Repair can be made or is unnecessary.
3- Faulty margins that cannot be properly repaired. Penetrating discoloration along margin of restoration in pulpal direction. Visible ditching along the margin.
4- Mobile or fractured restoration. Caries continuous with restoration margin. Tooth structure is fractured.

Fig. 2. Modified CDA-scale used in the present study to assess clinical outcomes of each restoration.

Technical complications were registered dichotomous as *yes* or *no*. Infraction was registered as *yes* if there was a visible crack in the surface. Chipping was registered as *yes* with surface loss of ceramic not depending on size of fracture area, and was further specified according to localization on the crown (mesial, distal, cusp or buccal/labial surface). Total fracture was registered as *yes* when there was loss of ceramic and exposure of underlying tooth substance. Loss of crown was registered as *yes* when the crown was lost or could be removed with minimal force. Wear facet was registered as *yes* when visible on the articulating surface of the crown. Marginal fit was registered as *excellent* when the crown margins were undetectable when probing and *satisfactory* when slightly detectable, but not still too short, not too over-contoured and no distinct marginal gap. It was registered as *unsatisfactory* when the margins were distinctly too short, grossly over-contoured relative to unprepared tooth cervical contour, or when the probe "hooked" between crown and tooth substance (probe-resistance). Fractured crowns were retrieved and analysed by fractographic methods to find fracture origins and fracture modes [12].

Chipped crowns were cleaned with ethanol, before a precision impression was taken for making an epoxy replica for analysis in a Scanning Electron Microscope (SEM) [13].

The patient reported outcomes were registered on a self-administered questionnaire containing six items on a four-graded Likert scale ranging from *"very satisfied"* to *"dissatisfied"*. Further, two questions regarding potential problems and choice of treatment with *yes* and *no* as possible responses (Fig. 6).

3.1. Statistical analyses

The data was analysed using descriptive analyses. The clinical outcomes are presented as frequencies both at the crown level and patient level. Patient satisfaction is presented as success rates. Due to the low number of participants, no statistical correlation calculations could be performed with sufficient statistical power. Since most recordings were dichotomous, inter-examiner agreement calculations are given in percent.

4. Results

4.1. Biological findings

Only one examiner assessed biological findings. Visible plaque was found in two of the patients while BoP was found on one or more teeth in all patients. No caries was found in the restored teeth in any of the patients.

4.2. Technical findings and complications

One crown had a total fracture after 16 months and was replaced by a new monolithic zirconia crown. Hence the fractured crown could not be included in the clinical assessment, but is included in the overall calculation as a technical complication, in the group of total fracture. One patient with 10 crowns was evaluated by only one examiner since the patient had limited time available. One of the examiners missed to assess two crowns. In total one examiner assessed all 84 crowns, and the other 72 crowns. The rates are presented as the average of the two examiners recordings when possible.

4.3. CDA ratings

Almost all of the crowns (90.5%) had excellent surfaces and the rest was evaluated as satisfactory. The color was rated as satisfactory on all crowns. Most of the crowns (75.3%) had excellent shape whereas the remaining were evaluated as having a satisfactory shape. The crown margins were excellent in the majority of the crowns (66.8%) and satisfactory on the rest. Overall, all crowns were evaluated as 100% satisfactory and not in need of repair or remake regarding any of the CDA variables (Fig. 3). Inter-examiner agreement on the CDA ratings was 87.2% (range 75–100).

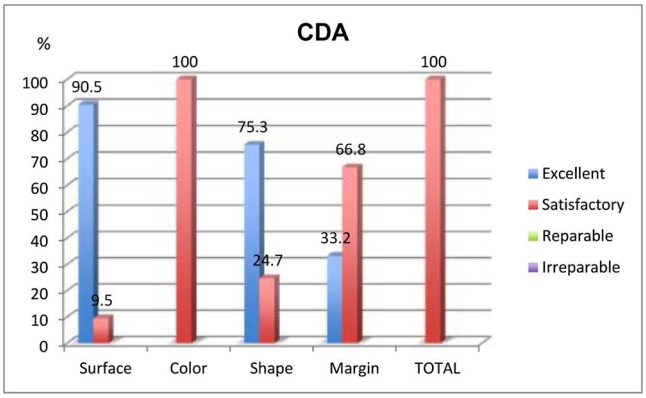

Fig. 3. A 3D-bar graph presenting clinical ratings of the crowns according to the modified CDA- scale. The bars are representing the results in percentage of the total.

Approximately 1/3 of the crowns had excellent margins, 1/5 of the crowns had slightly too short margins, and almost half of the crowns were slightly over-contoured (Fig. 4). One examiner found marginal gap on four crowns, and a possible infraction was registered in one crown. The majority of the crowns (n = 80, 94.1%) showed no signs of chipping. However, one patient had incisal chippings on four crowns (Fig. 5). The chippings occurred 1 month after the crowns were cemented. The fracture origins were from roughened areas on the palatal side on the incisal edge. One crown, in another patient, had a total fracture after 16 months and was replaced. The fracture origin was a defect in the crown margin in the mesial region causing a semilunar fracture on the buccal surface (Fig. 5). No other crowns were lost. Inter-examiner agreement on technical findings was 89.9% (range 72,2–100).

Registration of wear facets was registered with an agreement < 50%, and are not specified in the study.

4.4. Patient satisfaction

All 13 patients were satisfied with the monolithic zirconia crowns; indeed, the majority was very satisfied (Fig. 6). Hence, none of the patients reported dissatisfaction with the crowns. Regarding color, eight of the patients were satisfied and the rest were very satisfied. Five of the patients were satisfied with the shape of the crowns, whereas the rest were very satisfied. Six of the patients were very satisfied and equally many were satisfied with the chewing comfort. One patient reported to be slightly dissatisfied with the chewing comfort. All patients were satisfied with the cleaning accessibility of the crowns; four were very satisfied, the remaining was satisfied. Seven patients were satisfied and four were very satisfied with the preoperative information. Two patients were slightly dissatisfied with the preoperative information. Two patients reported some problems with their crowns; the patient who experienced chippings and the patient with one total fracture. Both these patients reported to be satisfied or very satisfied with all the self-reported variables. The remaining 11 patients reported no problems with the crowns. All patients would choose the same treatment modality if they were to be treated again.

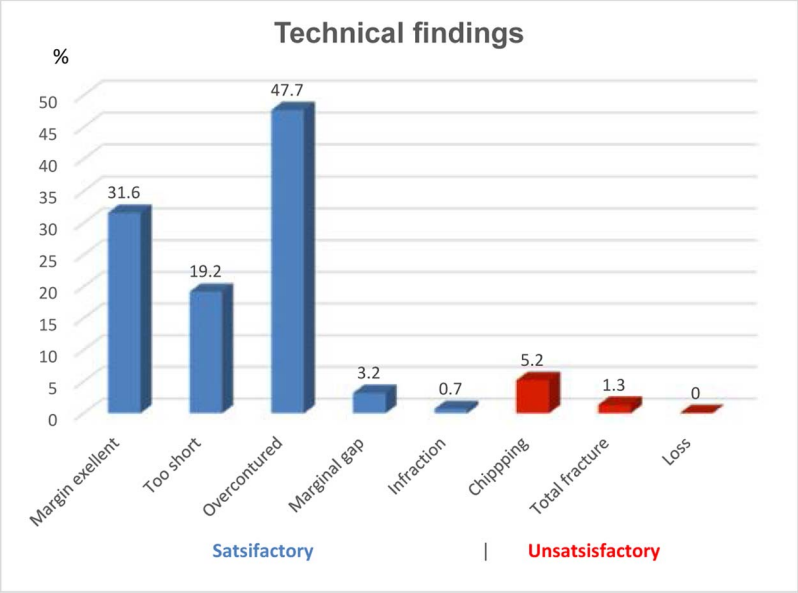

Fig. 4. A 3-D bar graph of technical findings and complication details of the crowns. The bars are representing the results in percentage of the total.

5. Discussion

The main findings in this study are that monolithic zirconia crowns show a low level of complications and are well accepted by patients. All the patients in the present study were heavy grinders with severe tooth wear prior to restorative treatment and such patients are very often excluded from studies on survival and success of crowns. A higher rate of technical complications is expected in this group of patients[1].

A recent consensus report summarizes that minimal invasive treatment with composite build-ups should be the first option of treatment when necessary [14].

The patients in this study had a long experience of failed restorations and wanted restorations with better durability than previous treatment. Treating patients with composites shows good results, but technical complications are expected [15–17], and for some patients minimal invasive treatment will not be satisfactory. The low rate of complications in this study shows that monolithic zirconia crowns may be a valid treatment alternative if complication rate of previous treatment is too high for the patient or the practitioner, but more studies are needed to confirm this.

The low chipping rates, despite the patient group in the present study, can most likely be explained by fracture-resistant properties of the monolithic structure of the crowns. Cumulative ceramic 5-year chipping rates for densely sintered zirconia crowns were found to be 3.1% in a recent systematic review [3]. An important aspect is that several of the included studies had excluded patients with bruxism and parafunctional habits. The results are therefore not directly comparable to the results from our study where these patients are included. There are studies that reports of higher chipping rates (8–54%) for veneered zirconia and parafunctional activities and absence of occlusal night guard was considered as major risk factors [6,8,18]. As the participants in our study did not wear occlusal night guards despite their parafunction, high rates of chipping could have been expected.

Due to the limited number of fractures in the present material, it is difficult to draw any conclusions for the reason of the fractures. Extreme parafunction might be one reason as the fractures occurred shortly after cementation. The fractographic analyses show obvious signs of severe wear in the close proximities to the origin of all the chips, and this is considered the most reasonable cause of fracture. A defect in the crown margin is suspected to be the reason for the margin fracture seen in Fig. 7. The manufacturing process may have introduced defects in the restorations before cementation, which may have reduced the fracture resistance of the crowns [19]. Low temperature degradation (LTD) can also be the cause of these failures. In stabilized monolithic zirconia the metastable tetragonal phase transforms into a monoclinic phase in humid environment, and is called LTD [20–22]. This phenomenon starts at the surface and propagates into the material. Chewing forces might have induced phase transformation around micro-cracks in the surface, leading to chipping of the outer surface [23], but it seems unlikely that it is the reason for the total fracture due the short time of function.

The two patients that reported problems with the crowns, one with chipping on four crowns, and one with a total fracture, were satisfied with the treatment in general. The chipping surfaces were small and could easily be polished and a new monolithic zirconia crown replaced the fractured crown. Probably they experienced the remediation as small relative to the aesthetic and functional improvement they had achieved from the rehabilitation of the dentition.

An increase in vertical dimensions of the patients was necessary to achieve acceptable aesthetic and material dimension. High adaptation capacity by the patient for new vertical dimension can be expected [24,25]. At the clinical examination 1–3 years after treatment all patients had even distribution of occluding contacts in anterior and posterior segments. This shows that an adaptation has occurred [17,26]. None of the patients in this study reported any problems regarding the adaptation.

Monolithic zirconia has a monochromic color-structure and an opaque appearance. Due to these optical properties, it is not possible to imitate the natural optical properties of the original tooth substance. This explains why all crowns are rated as satisfactory and not excellent in color scores. In comparison, a study by Håff et al. reported 45% acceptable color on monolithic zirconia crowns, explained by a slight mismatch in color between the restoration and the adjacent tooth structure [27]. They considered the color as 55% excellent even with the optical restrictions in monolithic zirconia. As the main preference for the patients in our study was strength and durability of the crowns, this has probably influenced the patients‘ acceptance of the suboptimal aesthetic properties of the monolithic zirconia crowns.

The surfaces of the monolithic zirconia crowns were found to be mostly excellent. The crown surfaces rated as satisfactory were minimally rough or pitted on the surface, but close to excellent. Ideally, all types of crowns should have a smooth surface prior to clinical function. Roughness or pitting of the surface is normally a result of wear of the surface due to antagonist contact. A possible contributory factor on

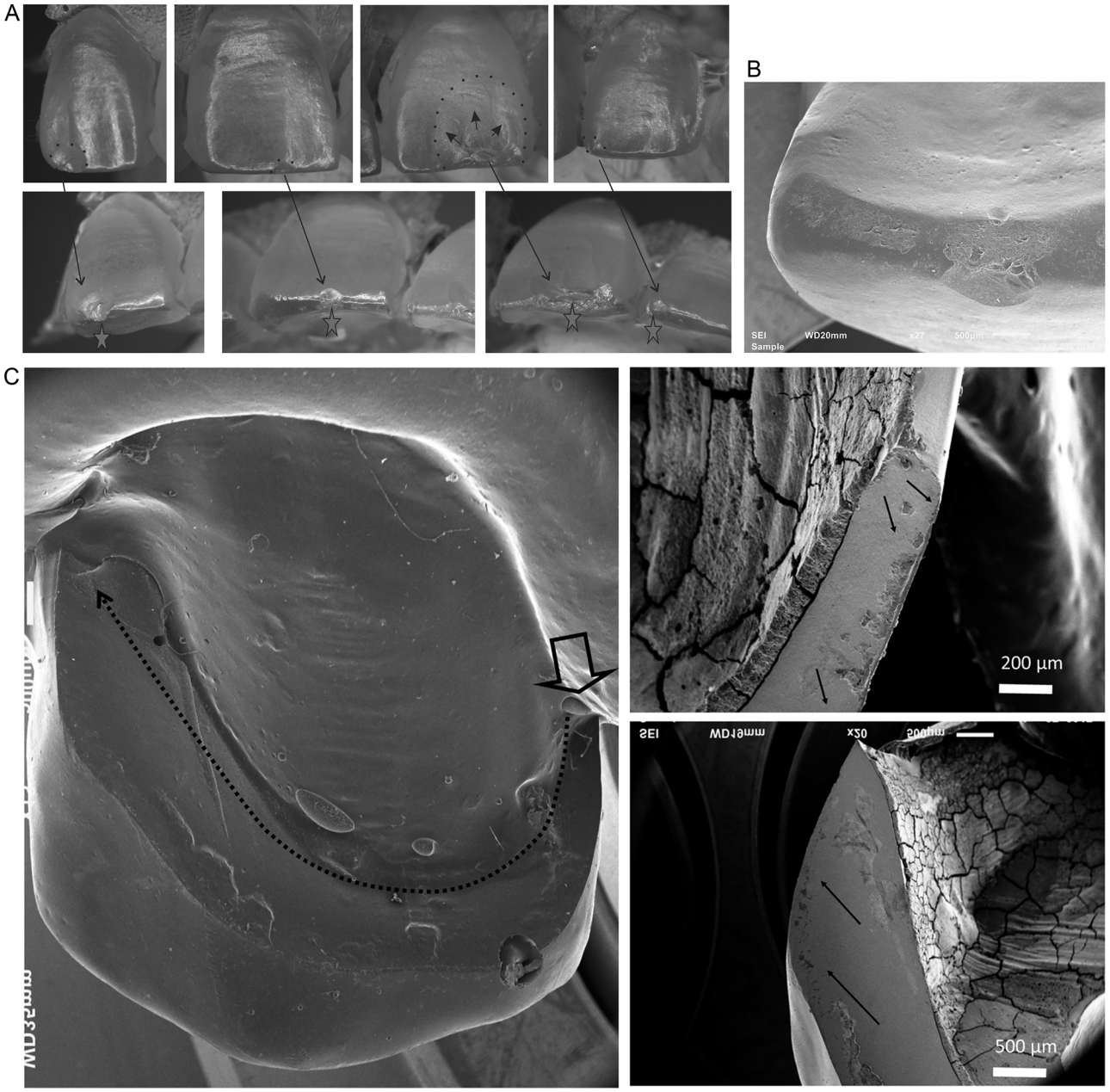

Fig. 5. Chipping. A) Four crowns in one patient with incisal chipping. The fracture origins were all in areas of surface wear (stars) B) Wear facets at the incisal edge are the obvious cause of the chipping as seen in SEM images of the epoxy model of one chipped crown. C) Core fracture. One crown was replaced after 16 months due to core fracture splitting the crown in two (left). The fracture origin was in the mesial crown margin (open black arrow) as seen on a SEM image of an epoxy model based on an impression taken of the remaining piece in situ. The crack propagation (dotted arrow) was identified by the direction of the hackle lines (black arrows) as observed in higher magnification SEM on the retrieved pieces. A minor crack can be observed at site of origin at the inside of the crown margin.

surface quality concerning monolithic zirconia is the effect of LTD [23], which in combination with wear might cause increased surface roughness. The clinical relevance of LTD in this context is uncertain.

The digital design technique limits creation of anatomic details, and may result in a deviant shape of the crowns. Still, most of the crowns were rated as excellent in anatomy. Digital mouse-controlled crown design is a completely different procedure than the classical handmade wax-up technique and may have an effect on the anatomical design of the crowns.

The margins were all satisfactory, and the suboptimal features were just distinguishable during probing. The preparation margins were all shallow chamfer-shaped and supra-gingival, and should be easily detected on a plaster model. A deviance in defining preparation margins on the model is an unlikely cause for some short crown margins. In comparison, Cehreli found suboptimal margins on 26% and 6% not acceptable (one crown) of In-Ceram Zirconia crowns, and 20% of Ceron Zirconia crowns [28]. The manufacturing process can probably explain the different results on crown margins in this report. In our study, only a few crowns were registered with marginal gap.

Registration of wear facets was performed with an inter-examiner agreement of 47.2% and hence could not be interpreted for any conclusions. One reason for the low agreement might be that wear facets were difficult to differentiate from the anatomic surface and color of the crowns. The monochrome nature of the crowns means that there will be no change in color or surface texture during surface wear. This makes it difficult to monitor the patients' grinding activity.

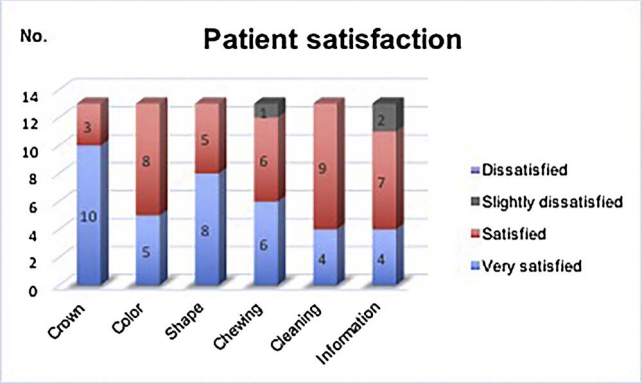

Fig. 6. A 3D-bar graph of patient reported outcomes according to the self-administered questionnaire. The bars are representing the distribution of the sample expressed in color codes.

6. Conclusion

Within the limitations of this observational case-series study, we conclude that monolithic zirconia crown restorations in the aesthetic zone in heavy grinders show minor clinical complications and that patientś satisfaction is acceptable. Monolithic zirconia crowns may provide a valid treatment modality of severe tooth wear in the aesthetic zone where minimal invasive treatment fails.

Conflict of interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

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